GEO-ENVIRONMENTAL APPRAISAL AND THEIR HAZARDS IN WESTERN PART OF YAMUNA BASIN, U.P. (INDIA)

ABSTRACT

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

Doctor of Philosophy

IN

GEOLOGY

By

ASHISH DUTT

DEPARTMENT OF GEOLOGY
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

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ABSTRACT

The environment is the sum of all external influences and conditions affecting life and development of organism. The intensity of man's activities, diversity and magnitude of different types of waste introduced into the environment are increasing at an alarming rate. Environmental pollution is generally referred as the unfavorable alteration of our surroundings and occurs mainly because of the action of the men. Environmental pollution take place through changes in energy patterns, radiation levels, physical and chemical constitutions and abundance of organism.

In the area of study, the Yamuna river are highly polluted in the north-western region, as they receives a major share of pollutants from some of the biggest industrial estates all along the course in the north western Uttar Pradesh. The worst polluted part of the Yamuna river lies between Delhi and Ghaziabad, where the water receives industrial wastes from tanneries, textile mills, chemical distilleries, sugar factories, thermal power houses and metal based industries. Besides, it is also receiving a large number of untreated urban and domestic wastes from the seven drains of the metropolitan Delhi and its adjoining areas.

In the present study an attempt has been made to find out the causes and sources of pollutants, their viability and statistical correlation, if any, in their major and trace metal contents.

The study area lies between the latitude 28°27'30" and 28°42'30" and longitudes 77°17'309" which falls under the survey of India topsheet no H/I. The area falling in the national capital region is densely inhabited regions of the country. It is a part of Ganga- Yamuna doab and covers an area of about 2596 sq.km. The total population of the area is about 20.5 lacs.

Physiographically the area has been divided into three distinct geomorphic units i.e. rocky surface, flood plains and higher alluvial surface. The area is drained by river Yamuna which shows distinct braided character. The Ganga basin of Indogangatic plain froms the largest ground water reservoir in India and it considered to be formed as a result of continent to continent collision between Indian and Asian plates. Higher alluvial surface in the area is drained by the Yamuna river. The Yamuna and Hindon rivers comprises the main drainage system in the study area. The major source of the recharge of the ground water bodies in the upper Ganga canal which flows through eastern end of Greater Noida.

The area falls under the sub-tropical climatic zone with extremes in summer and winter. The temperature rise upto 44°C or even more during May. The average rainfall in Ghaziabad is about 871.46 mm. The precipitation arises from south west monsoon to September and accounts for nearly 80 to 90% of annual rainfall. The remaining 10 to 20% of rainfall occur from January to March.

Geologically the area under investigation are characterized by the presence of thick pile of Quaternary alluvial deposits laid down by the action of river Yamuna.

The study area is the part of great alluvial tract of the Indo- Gangetic alluvial plain. The Indo-Gangetic plain is supposed to be one of the best ground water reservoirs of the country. The lithologs of the tubewells drilled in the study area show that the alluvium within 40 to 50 m depth comprises mainly of sand with clay and kankar intercalations and is predominantly clayey at deeper levels. Gravel and calcium carbonate concretions are quite common at shallow depth as thin beds and lenses or as nodules disseminated in clay. The quaternary alluvium comprising sands of various grades, clay and silt intercalated with 'kankar' the various sand bodies forms the prolific aquifers. Groundwater occurs under semi-confined to unconfined conditions.

On observation of the fence diagram it is clear that, there exists a multi-aquifer systems in the area. The top aquifer is unconfined in nature in general. Alternate clay and kankar beds indicate the deeper aquifers to be leaky confined in nature, fine to medium grained sand constitute the aquifer material. Layers of coarse sand are met occasionally in the area. Two or three layers of aquifer, ranging in total thickness 15 to 20 mts. Alluvial deposits are highly porous and permeable because of the presence of sand and kankar. Groundwater occurs in the pore spaces of alluvial sediments in the zone of saturation.

Networks of 65 observation wells were established and relevant hydrological data were collected. Water level measured in the observation wells are presented as pre-monsoon and post-monsoon. The detailed survey revealed that, the depth to water level in the entire region, is observed within a range of 2.92 mts to 12.5 mbgl. The water level fluctuation indicating different fluctuation zones revealed the quantum of seasonal fluctuation. Seasonal fluctuation in water level varied from 0.17 to 1.7 m in 2006 and 0.22 to 2.33 m in 2007.

The rapid industrialization, urbanization and anthropogenic activity in the study area have caused Geo-environmental degradation of the area which has also resulted in ecological disturbances, increase in environmental pollution and decline in the available natural resources of the region. Several Geo-environmental hazards have been operated in the study area viz. degradation of agricultural land due to urbanization, adverse environmental impact due to brick kilns, mining, water logging, due to canal induced seepage and shallow water table conditions, flooding during heavy rain fall, poor drainage system and unplanned development of unauthorized colonies on the flood plain of rivers. Noida and Ghaziabad are the most industrialized towns of Northern India and it has a significant role in the economy of country. A large number of industries located in the research area discharging their effluents without proper treatment and recycling into the Yamuna and Hindon river, the solid waste from the various factories in the existing depression (landfill sites), consequently polluting the surface and sub surface water bodies.

The chemical quality of water in parts of Yamuna river sub basin has been taken up from the analysis of 120 ground water samples for the study to evaluate it suitability for irrigation and drinking purposes. The physico- chemical analysis of the ground water samples have been collected from the various locations. The ground water in the area is hard and alkaline in nature. The chemical analysis of ground water / soil for major ions and heavy metals revealed that the concentration of major ions are very high and some of the toxic metals (Cd,Cr,Pb) present in ground water are more then the concentration of WHO (1993) permissible limit.

The wide spread practice of dumping raw sewage in shallow soak pits has made witnessed the groundwater pollutants in the area. Abnormally higher levels of trace elements found near the industrial areas indicating the effects of effluents on ground water quality.

The plotting of analytical results show that sodium or potassium are the dominant facies among the cations and majority among the anion facies of shows the sulphate and bicarbonate type of water. Correlation coefficients among various chemical variables have been determined to study the relationship among quality parameters and it show a high correlation between Na, K and Cl in post-monsoon samples. On the basis of X-Y plot the groundwater in the area has been classified in two groups $HCO_3^- > Cl^- + SO_4^-$ and $Cl^- + SO_4^- < HCO_3^-$. $Ca^{++} + Mg^{++}$ and HCO_3 with moderate good correlation of pre- and post-monsoon samples and Ca-SO_4 plot suggests abundance of SO_4^{--} compared that of Ca^{++}.

Ground water pollution in the basin is mainly due to indiscriminate disposal of industrial wastes on land and surface water channels. Present investigation has revealed that the ground water is characterized by high content of pollutants as evident from high concentrations of toxic metals.

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Dedicated
to my
Parents
&
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CERTIFICATE

This is to certify that the work presented in this thesis entitled **"Geo-Environmental Appraisal and their Hazards in the western part of Yamuna basin U.P. India"** has been carried out and completed under my supervision in the field of Hydrogeology/Environmental Geology at the Department of Geology, Aligarh Muslim University, Aligarh.

The work is an original contribution to existing knowledge of the subject. I recommended that **Mr. Ashish Dutt** be allowed to submit the thesis for the award of Degree of **Doctor of Philosophy** in Geology of the Aligarh Muslim University, Aligarh.

2/9/08

(Dr. Shadab Khurshid)
Sr. Reader

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(Ashish Dutt)

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1.1 GENERAL

The McGraw-Hill Encyclopedia of Environmental Science (1975) defines environment as the "Sum total of all conditions and influences that affect the development and life of organisms". Thus every living organism from the lowest unicellular micro-organism to man require ecological setting conducive for their survival. The ecological settings are interlinked and interdependent. All the elements of our planet also have closed bonds and cycle and many are interlinked with and form essential minor/major constituents of the biotic system and require ecological settings. Thus the atmosphere, ocean and the hard crust of the earth and the biota surviving are closely interconnected. Historically, we in India have been conscious about environment since *Vedic* time and the basic philosophy has been of harmony with nature.

Natural system consists of a mosaic of different rock types, soils, rivers, valley hillsides and vegetational changes. Natural geoenvironmental scenario represents the aggregate of growth and development. generating from the harmonious interaction between the biotic and the abiotic components. The functional role of each of these discrete parts of the ecosystem also contribute to different constraints in the environmental planning matrix. Thus, even if we may integrate human works and activities with our natural environment. To ensure sustainable development of an area, proper understanding and assessment of the various prevailing environmental parameters are essential. Any factor, that disturbs the delicate balance between these natural system may emanate a chain reaction, and after the sustainable limit is crossed, eventually end up in drastic permanent changes in the ecosystems. Time has come to recognise sustainability in development in our planning process as one of the basic and permanent objective. However, sustainable development needs to be properly paraphrased.

Mineral resources form a major constituent of the natural condition. There are enormous quantities of different minerals and ores that are to be mined to meet the industrial and economical demand. Exploitation of these non-renewable resources is increasing exponentially. Keeping in pace with the national development, there exists an overall apprehension, that environmental degradation connected to natural resources beyond sustainable limit possibly will lead to an irreversible geoenvironmental situation. For assessing the prevailing state of environment, environmental appraisal studies are carried out with regard to the existing environmental parameters. Imprints of such destabilised environmental scenarios may already be emerging out from different coner of the country where large scale exploitation of various minerals are taking place. The resource demand and sustainability thus attain great significance and have to be dealt scientifically and in comprehensive manner. (Shome.S.K,*1992*).

Land and water are very cherished and valuable components of ecosystem, preservation of which is obligatory responsibility of the civilised society for its own survival. It is obvious that large scale uncontrolled exploitation of land and water resources by mining and industrial activities for sustained development is expected to leave deep imprints on geoenvironmental scenario. Such irreparable damage in the *long run is likely to endanger the existing ecological balance of* interdependency between biotic and abiotic components. (Ravi Shanker, 1992).

These studies were initiated with the objective of assessing the nature and trend of degeneration of landform and water regime due to uncontrolled mining *vis-a-vis* generation of suitable geoenvironmentally compatible rehabilitation module. Successive landuse maps on large scale which indicated the qualitative trend of changes quantifying the gradual process of degeneration. Chemical degeneration of soil and water due to trace elements present in water and associated sediments was also kept under the preview of this study.

Environment is an all encompassing term embracing atmosphere, hydrosphere and lithosphere. The biotic component of environment is totally dependent for its existence on these three cornerstones. The lithosphere comprises rocks in all its manifestation including micro to global scale geological structures and soils which are basically derived from the rocks. The geological processes operating over many millennia have shaped the landscape (geography and geomorphology) all over the world and in which all terrestrial living being reside. The hydrosphere encompasses surface water of all description including the polar caps, glaciers, oceans, surface and groundwater, which constitutes the habitate of all aquatic life forms. This is again governed by well defined geological processes/cycles. In addition to many other factors, the composition of the atmosphere-and climates, too, are influenced by geological processes like volcanism. It is more than evident, to understand the effects of land-water-air system on 'Mankind' a proper appreciation of the earth sciences is necessary. The earth sciences processes as also the environment is a dynamic phenomenon undergoing continuous change. (Ravi Shanker and S. Shome 1997).

Water is a prime natural resource, a basic human need and a precious national asset. Planning, development and management of water resources need to be governed by national perspective. Water is a scarce and precious national resource to be planed, developed, conserved and managed as such, and on an integrated and environmentally sound basis, keeping in view the socio-economic aspects and need of the States. It is one of the most crucial elements in development planning. As the country has entered the 21st century, efforts to develop, conserve, utilize and manage this important resource in a sustainable manner, have to guided by the national perspective.

Growth process and the expansion of economic activities inevitable lead to increase demand for water for diverse purposes domestic, industrial, agricultural, hydropower, thermal-power, navigation, recreation etc. So far, the major consumptive use of water has been for irrigation. While the gross irrigation potential is estimated to have increased from 19.5 million hectare at the time of independence to about 95 million hectare by the end of the year 2004, further development of a substantial order is necessary, if the food and fiber needs of our growing population are to be met with. The country's population which is over 1027 million (2001 AD) at present is expected to reach a level of around 1390 million by 2025 AD. (State Gazette, Uttar Pradesh, 2004).

Another important aspect is water quality. Improvement in existing strategies, innovation of new techniques resting on a strong science and technology base are needed to eliminate the pollution of surface and ground water resources, to improve water quality. Science and technology and training have play important role in water resources development and management. National water policy was adopted in September, 1987. Since then, a number of issues and challenges have emerged in the development and management of the water resource.

Non-conventional methods for utilisation of water such as through inter-basin transfers, artificial recharge of ground water and desalination of brackish or sea water as well as traditional water conservation practices like rain water harvesting, including roof top rain water harvesting, need to be practiced to further increase the utilizable water resources. Water resources development and management will have to be planned for a hydrological unit such as drainage basin as a whole or for a sub-basin, multi-sectorally, taking into account surface and ground water for sustainable use incorporating quantity aspects as well as environmental consideration. All individual development projects and proposals should be formulated and considered within the framework of such an over all plane, keeping in view the existing agreements awards for a basin or a sub-basin so, that the best possible combination of options can be selected and sustained.

Exploitation of ground water resources should be so, regulated as not to exceed the recharging possibilities, as also to ensure social equity. The detrimental environmental consequences of over exploitation of ground water need to be effectively prevented by the Central and State

Governments. Ground water recharge projects should be developed and implemented for improving both the quality and availability of ground water resources. (Ministry of Water Resources,2004).

The environment is the sum of all external influences and conditions affecting life and development of organism. The intensity of man's activities, diversity and magnitude of different types of waters introduced into the environment are increasing at an alarming rate. Environmental pollution is generally referred as the unfavorable alteration of our surroundings and occurs mainly because of the action of the men. Environmental pollution take place through changes in energy patterns, radiation levels, physical and chemical constitutions and abundance of organism.

Water is among the most essential requisites that nature provides to sustain life for plants, animals and humans. The total quantity of fresh water on earth could satisfy all needs of the human population, where, it evenly distributed and accessible (Bobba et al. 1977). The availability of water resources has been the essence for establishment and growth of human population. This developmental activity of human being with time led to establishment of industries around the water resources which in turn attracted more population, as a result of this cycle, water resources are becoming exhausted.

India has been gifted with substantial water resources. Population explosion and industrialization have enhanced the demand of water significantly. Consequently to meet, this increaser in demand, continual development of new sources of water for irrigation, hydropower, domestic and industrial supply is needed. Water being the most vital resources for all kinds of life on this planet and is also the resource adversely affected by all kinds of human activities on land, in air or in water.

With the declared objectives of providing at least the basic amenities, there has been a tremendous development in India in the agriculture and industrial sector, with concomitant pressure on the fresh water. Groundwater utilization has increased immensely for irrigation, domestic and industrial purposes. Groundwater, like any other resources is likely to become scares if, its use is not properly regulated. Over exploitation and unrestricted development of groundwater have resulted in the depletion of water levels, failure of abstraction structures and deterioration of groundwater quality.

The rapid pace of urbanization, industrialization as well as agricultural activities have made environmental pollution a growing concern globally. The most important cause of groundwater pollution is unplanned urban development without adequate attention to sewage and waste disposal. Indiscriminate disposal of both hazardous and non-hazardous industrial water has further aggravated problems associated with water resource for drinking and irrigation. The deterioration of groundwater quality due to industrial effluents and municipal wastes in the study area is a live example. The waste generated by anthropogenic activities has not only polluted the environment as a whole but had a particular detrimental effect on the quality of aquato-envision too.

1.2 RESEARCH AREA

The study area is the most industrialized districts adjoining National Capital Territory of Delhi located on the fringe of the Yamuna river. There are thousands of industries manufacturing electrical goods, general engineering equipments, tractors, transport and agricultural implements, chemical industries, Electro plating, leather, rubber, tyre, paper, plastic and other products. Apart from industrial growth there has been remarkable development in the field of agriculture. This development in industrial and agricultural sector has resulted in the over exploitation of groundwater and deterioration of both surface and sub-surface water quality in the research area.

Part of study area falling in the National Capital Region which is one of the most densely inhabited regions of the country. The anthropogenic processes including the rapid urbanization (settlement of colonies) and industrialization (growth of major and minor industries) have been taken around study area. Besides this, causes of floods and their impact on environment, water logging problems, mining activities and degradation of water quality due to effluent discharge from various type industries in the natural water system and landfills, are some of the geo-environmental problems associated to the study area. The interference with the geo-environmental system has resulted in a series of imbalance leading to severe geo-environmental degradation.

An attempt has also been made to find out the statistical relationship of major and trace elements in the area. Such studies will also be helpful to find out the probable source of water pollution which might be utilized for suggesting remedial measures for future.

Keeping in view of the above, the present investigation has been carried out in parts of Yamuna river sub-basin as part of Ph.D. programme. The study covers various aspects of pollutional assessment, evaluation of aquifer system and their disposition, and groundwater quality status in the basin.

1.3 LOCATION OF RESEARCH AREA

Noida and Ghaziabad are two major districts constitute the major part of the study area. Noida and Ghaziabad are located on the eastern fringe of river Yamuna Noida lies within latitudes 28°27'30" and

28°42'30" and longitudes 77°17'309" and 77°27'30". Ghaziabad lies between latitudes 28°20'and 28 °37'30" and longitudes 77°25' and 77 °42'30". (Fig 1.1)

The Noida is located on the east of New Delhi across the river on its left fringe, while Ghaziabad is located further east across the river Hindon on its left alluvial plain and Sahibabad on the north. Grand Trunk Road on the east, Dankaur – Sikandrabad lies in the south and river Yamuna on the west, while Noida is located adjacent to National capital Territory . Greater Noida is located 15kms from the U.P.Delhi border and 30 Kms from Income Tax Office (I.T.O). It is also connected by roads, railway track of Kolkata. The communication and approach will further improve in future when the existing Road Noida-Surajpur-Dadri road is widened to accommodate Six-lane traffic.

The Greater Noida Industrial area covers a total area of about 33,566 hectares. The total geographical area is shown in the Table-1.1.

Table 1.1: Blocks and geographical areas in Hectares.

S. No.	Name of Block	Geographical Area (Ha)
1.	Dadri	4586
2.	Dankaur	13705
3.	Sikandrabad	1563
4.	Bisrakh	12340
	Total	**32194**

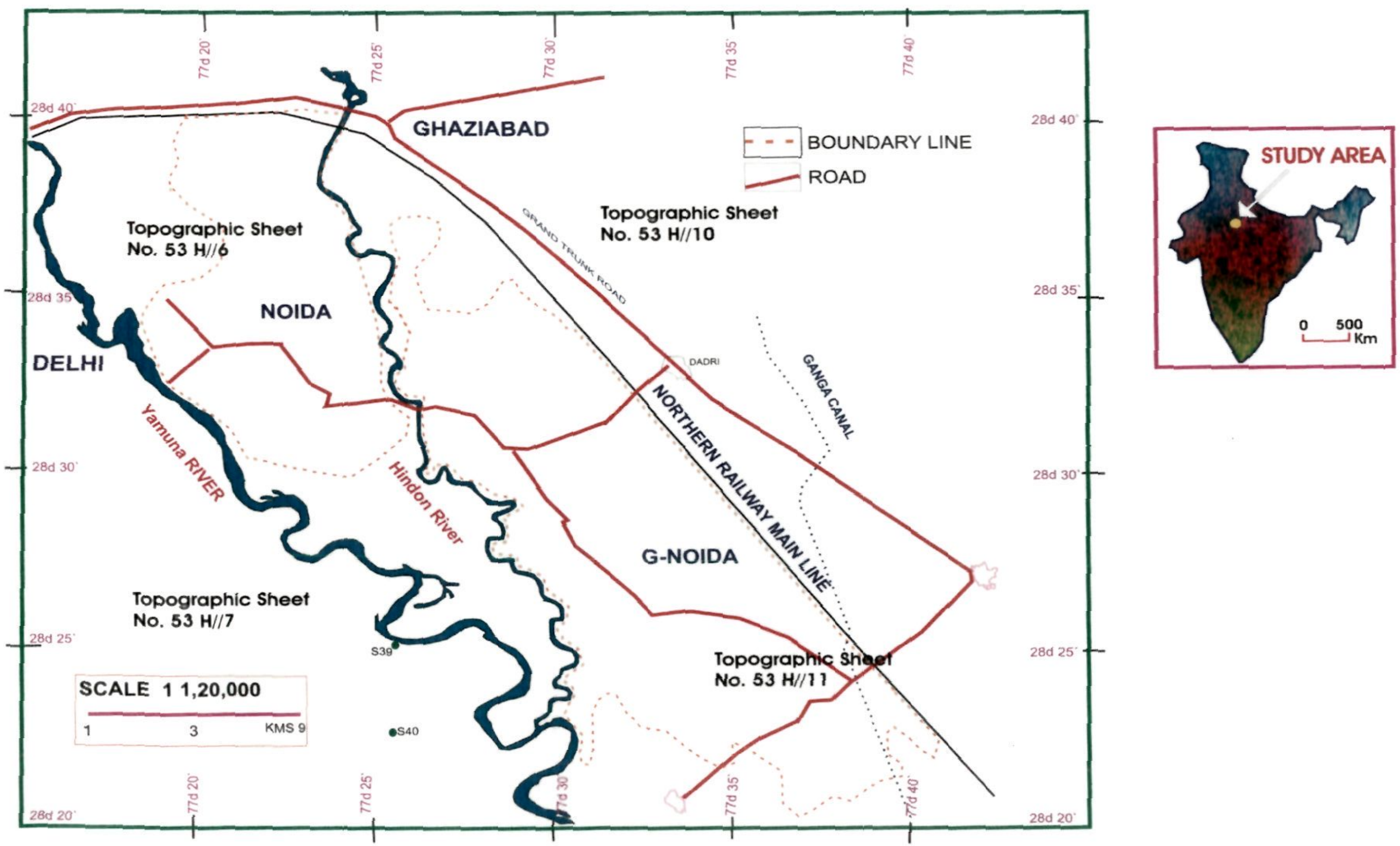

Fig.1.1. Location map of Noida and Grater Noida (Yamuna – Hindon sub basin).

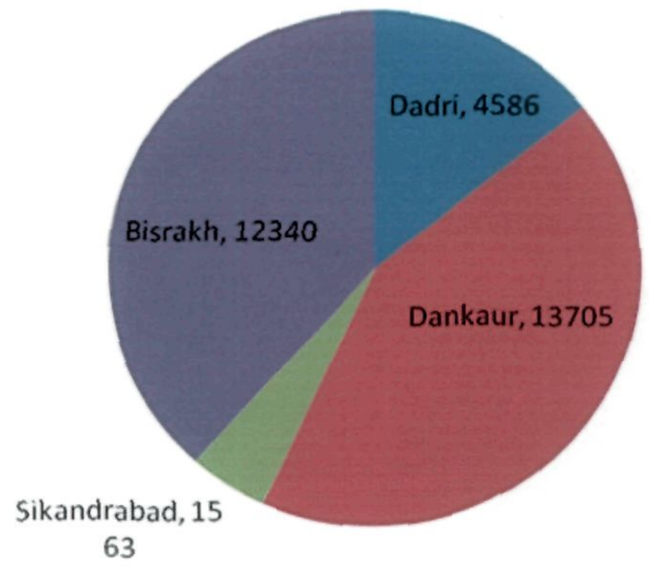

Fig 1.2: The total geographical area in Hectares.

1.4 AIMS AND OBJECTIVES

The rapid growth in population and industrialization has placed tremendous pressure both on land and water resources of the area. The groundwater quality is being deteriorated because of the discharge of industrial effluents without proper treatment in the open drains and surface water bodies, dumping of solid wastes in the vicinity of industries and percolation of leachates from landfills. Adverse impact of mining activities, flood inundation, bank erosion and water impounding associated with flood planes.

The technological advancement in the drilling activities, better development of pump sets, reduction in cost and availability of energy have led to a massive groundwater development. This has resulted in the decline of water levels at places as well as water logging condition in the areas close to canal and induced seepage, degradation of agricultural land into salt affected land. Keeping in view of above aspects, Attempts have been made to synthesize the geo-environmental studies associated with hydrogeological and hydrochemical data. Assessment and sources of pollution, demarcation of recharge and discharge areas, aquifer characteristics. Delineation of water bearing zones, movement of ground water and behavior of water level fluctuation in space and time as a part of Ph.D. programme.

1.5 METHODOLOGY

In order to generate the qualitative data a systematic groundwater surveys based on hydrogeological and hydrochemical parameters have been carried out to cover the different aspects of water Resources potential and water quality assessment. The methodologies have been adopted to carry out research work, used published literature of the subject related to geology, hydrogeology and groundwater pollution, and geoenvironmental information's from published unpublished reports of Geological Survey of India (G.S.I.), Central Groundwater Board (CGWB) and Pollution Control Board collected and thoroughly studied. Toposheets No-53 H/6, H/7, H/10, H/11 (1:50,000) used to prepare the base map of the study area. Collection of rainfall data during the last twelve years and calculated the mean, standard deviation, coefficient of variations, spatial and temporal variation to interpret the recharge frequency by natural ways. Networks of 55 observation wells have been established to generate hydrogeological data base. Monitoring of pre and post-monsoon ground water levels and to assess the changes in water levels fluctuation with respect to recharge and discharge, water level fluctuation maps have been prepared to study the groundwater movement and direction of flow. Lithological logs of tube wells are utilized for the preparation of hydrogeological cross sections and fence diagram to synthesise the aquifer system and their disposition.

Groundwater and soil samples analyzed for major and trace ions chemistry. Study has been conducted to identify the vertical and lateral variation in groundwater quality and to determine its suitability for domestic and agricultural purposes. Preparation of various chemical constituents maps to study the spatial changes in groundwater quality. Various chemical facies have been determined by plotting the hydrochemical data on Piper Trilinar and Wilcox pattern diagram. Correlation matrix of various chemical parameters measured in groundwater samples to investigate the relationship among various water quality parameters. Groundwater of the study area has been classified into different chemical facies on the basis of major ions concentrations.

Various mechanisms identified and presented, which are responsible for alteration in groundwater chemistry.

Major geoenvironmental problems and their hazards have been carried out in fast developing urbano-industrial scenario, culminating to increase high population. Water logging, flooding and unplanned mining activities resulting on high stress on the land – water resources including the degradation of agricultural land into salt affected land. Maps of soil, land uses and water logged area have been prepared to delineate the geoenvironmental hazards zones.

1.6 PREVIOUS WORK

The earliest geological mapping in the area was done by ***Heron (1971)***, grouped the hard rocks of Delhi into Alwar series of Delhi system. ***Taylor (1935)*** carried out statistical analysis of rainfall and water level data in parts of Ganga basin.

Auden (1936), has carried out hydrogeological investigations in gangetic alluvial tract of Uttar Pradesh and emphasized the need of occurrence and suitability of tube wells in the most potential zone for Groundwater.

Geddes (1960), Sharma et.al, (1973), Rao (1973) Pal and Bhattacharya, (1979), Srivastava, (1983), I.B.Singh (1987), Khan et al. (1988) Ghosh and Singh, (1988) discussed different aspects of geomorphology in Gangetic Alluvial plain and has a made systematic study on the sub-surface geology of the Indo-gangetic plains.

Bhatnagar et al. (1977), attempted deterministic approaches concerning groundwater balance were in upper Yamuna basin. Sinha (1980) made an attempt to geology, geomorphology and hydrogeology in parts of Yamuna river basin.

Handa (1975,1981, 1983, 1986, 1987, 1988) made comprehensive study on hydrochemistry, groundwater pollution and hydrogeology and discussed inter-relation of various major and trace elements in ground water. ***Kakar and Bhatnager (1983, 1985, 1989)*** have been carried out extensive works on groundwater pollution, groundwater resource potential and chemical quality of water in the Yamuna basin, including groundwater flow, movement of pollutants in saturated and unsaturated zone, their impact on groundwater quality in different zones using hydrochemical data.

Pathak et.al (1978, 1982, 1985, 1988), investigated groundwater resources and development potential not only in Indo-gangetic plain but other parts of India. ***Singh (1992),*** presented an brief account of the geological evolution of Gangetic plain.

Khurshid and Israili (1988) assessed the pollutional load and quality of water in western part of Yamuna river sub-basin.

Singh et al. (1993) described the regional extent and configuration of the hydrogeologic units that composed the Quaternary alluvial aquifers in Ghaziabad at depth of 100m.

Jain and Sharma (1997) provided an excellent account on relationship among water quality parameters and established that conductivity is strongly and positively correlated with chloride, sodium, potassium and Total Dissolved Solids (TDS). ***Johanson and Carlson (1976), Ehrig (1983), Christenson et al. (1994). Boating and Jeffrey (1999)*** developed a two dimensional probabilistic transport model to carry out sensitivity analysis of contaminant transport in unsaturated zone.

Rao and Raju (1972) made detailed investigations of the hydrological conditions through large scale exploratory drilling, delineating of aquifer system and determination of aquifer characteristic by conducting pumping test and data analysis. ***Bhattacharya (1976,77)*** and ***Sinha (1978,90)*** discovered sediments of Quaternary age and the groundwater occurs in unconfined to confined conditions. ***Malviya,(1973,74)*** and ***Mahmood (1984,85)*** also in opinion that the groundwater in the area occurs under confined and unconfined conditions. They further stated that the sub-surface geology of the area indicates the existence of adequate thickness of the granular zones.

According to ***Jain (2004),*** the toxicity and fate of the water borne metals like Cu, Cd and Zn on bed sediments of river Yamuna, is dependent on its chemical form and therefore quantification of the different forms of metal is more meaningful than the estimation of its total metal concentrations. ***Jain et al (2004)*** have studied Zinc metal in bed sediments of river Hindon and concluded that the pollution from industrial and agricultural sources to a great extent is responsible for high concentration of zinc in river water.

Ashish, (2005). carried out detailed geo environmental and hydrogeological investigation in Ghaziabad district and found that the groundwater pollution has reached to a critical level and recommended that further groundwater abstraction from the shallow aquifer should be restricted.

CHAPTER-II

PHYSIOGRAPHY AND GEOMORPHOLOGY

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2.1 PHYSIOGRAPHY

India has been divided into three distinct physiographic units viz: the Peninsular Shield, Extra Peninsula and Indo-gangetic plain (Fig 2.1). The study area forms a part of the middle reaches of the Yamuna river sub-basin of Ganga plain which itself constitutes a part of the Indo-gangetic plain. Indo-gangetic plain is the largest alluvial plain of the world, which has been formed by deposition of terrigenous clastic sediments through the streams of Indus, Ganga and Brahmaputra river systems (Singh, 1992). The area under investigation forming parts of Noida and Ghaziabad districts of Uttar Pradesh respectively extends on both the fringe of the Yamuna and is developed by the alluvial deposits over a large part.

Indo-gangetic plain extends upto low peneplained ridges of Precambrian Aravalli chain. Area to the southeast and northeast of this rocky surface upto and beyond the Yamuna is a vast gently sloping alluvial deposits with intervening low land characterized by subdued microrelief representing the flood plains.

Physiographically, the study area can be divided into three distinct sub-divisions:

(i) Rocky Surface
(ii) Higher Alluvial Surface
(iii) Flood Plains

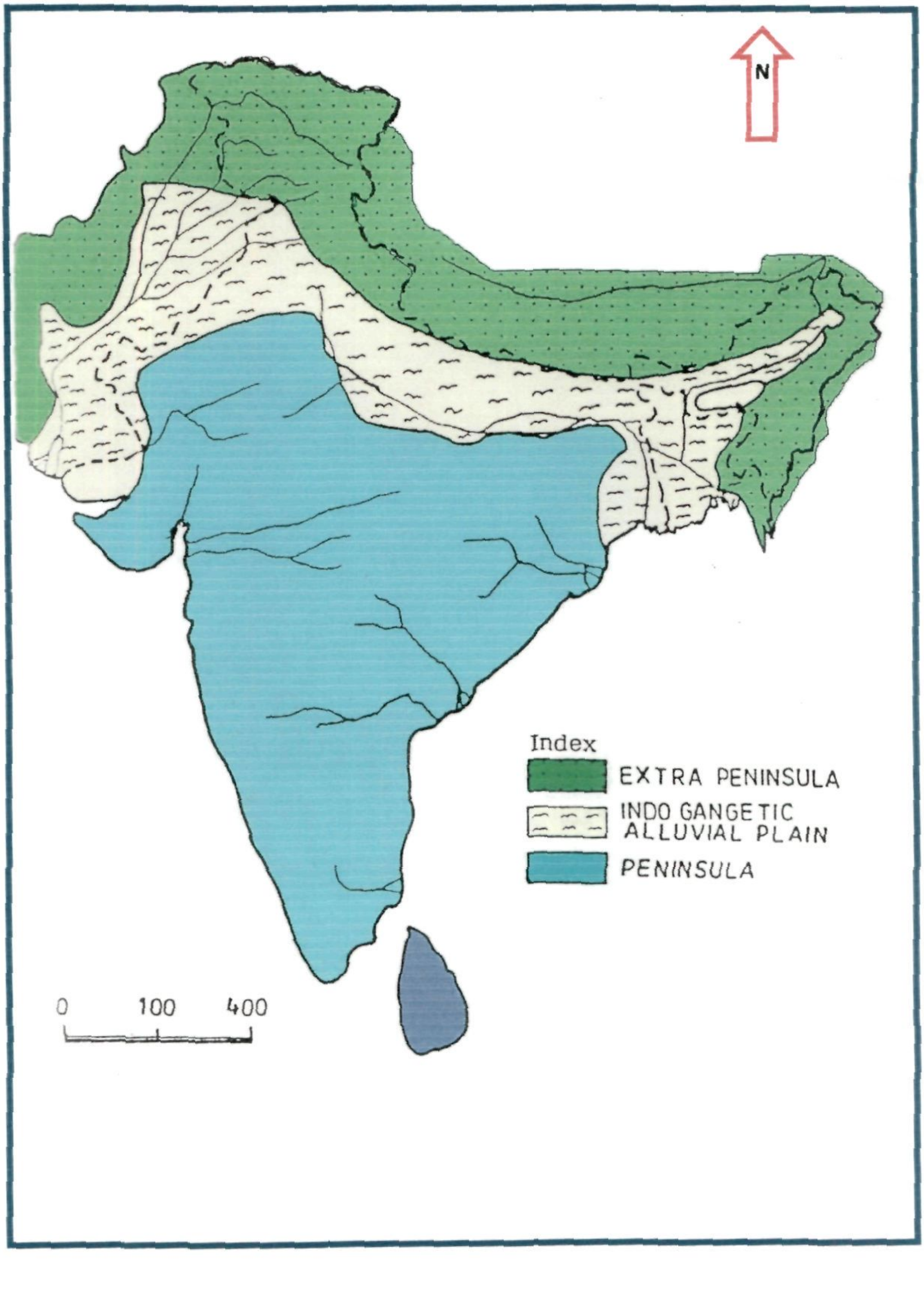

Fig.2.1. Physiographic division of India.

2.1.1 Rocky Surface

The western part of the area is occupied by peneplained ridges of Aravalli mountain chain. These ridges are flat-topped and do not show appreciable differences and hence bears the look of plateau They are the south-eastern extension of the main ridge system. The rocky surface appears to be elongated in a general N-S to NNE-SSW direction with elevation varying from 213 m to 314 m relative to surrounding plains.

The rocky surface has an over all slope towards north and east on the eastern side, the ridge slopes towards the Yamuna river with a gradient of about 3.3 m/km. On the southern side, it terminates abruptly plunging beneath the alluvium while towards north it gradually slopes beneath the alluvium. The rocky surface in the east and south is fringed by a narrow piedmont zone as observed near Badhkal. The zone is occupied by a thin soil cover composed of yellow gritty sand clay with irregularly dispersed angular rock fragments and kankar (calcareous nodules).

2.1.2 Higher Alluvial Surface

To the east and south of the rocky surface is an extensive alluvial tract designated as Surana - Noida surface by Sinha (1980). The surface has a general elevation of 224m above mean sea level in the northern part and slopes down southerly to an average elevation of 213m to 210 m from mean sea level. in the central part around Ghaziabad and finally an average altitude of 196-199 m in the southern part around Ballabgarh.

In the study area, no significant dissection or undulation is observed. In the southern and south- western parts, abandoned channels, cut off meanders, sandbars, levees and marshes etc, impart microrelief to the area Levees and sandbars occur in abundance in the south-western and western parts towards Atalli, Chhansa, Tilpat and Jasana locations.

Field scanning of LAND SAT imagery on 1: 50,000 scale by the Geological Survey of India revealed the presences of relict fluvial features over this surface, a lighter photo-tone, and a break in slope separating it from adjoining rocky surface. Higher alluvial surface in the area is drained by the Yamuna river. The lower plains are characterized by extensive agricultural activities and spatial disposition of wells and tubewells.

2.1.3 Flood Plain

There extends a low and even flat surface on either banks of the Yamuna called flood plains The flood plains are characterized by heterogeneity of land forms. There is a capping of greyish fine sand or slight greyish to greyish brown silt clay, often intercalated with calcareous concretions of varying sizes. A host of abandoned drainage channels have given rise to numerous lakes and marshy lands in this area.

The present day flood plains extend upto 2.5 km along either banks of the Yamuna However, They are well developed on the eastern bank with an average width of 2.5 km but upto 4 km at places The palaeo-channels of Yamuna river characterized by the 8-15 km wide river valley as compared to the present day 3-10 km wide floods plain *(Mukherji,1963)*. This indicate that earlier phase of the Yamuna has much larger carrying capacity with higher discharges.

During the last hundred years the river underwent a drastic change from meandering to present day braided type consequent to the decrease in water budget and increase in sediment load *(Singh, 1990)*. Due to construction of a barrage at Tajewala where the eastern and western Yamuna canals emerge leaving hardly any water in the channel on the down stream side.

At flood plains at least three major abandoned channels, two of these associated with levees and sand bars, occupy the central part in north-south direction. It is reported that thirty years back, the eastern part of these abandoned channels were ephimeral to river Hindon, The second channel is aligned in NW-SE direction and Joins the present day Yamuna flood plain.

Physiographically, the area has been divided into three distint region viz. flood prone area, upland tract and slightly depressed upland. Flood prone is associated with river Yamuna. The regional slope of the study area is from northwest to southeast. (Fig.2.2).

2.2 GEOMORPHOLOGY:

Geomorphic processes which have been operated in the area include fluvial, denudational and tectonic, the most significant being the fluvial process. The Yamuna comprises the main drainage system in the study area flowing towards southerly direction turning gradually in the south to south-eastward direction between Okhla and Manjhauli. This stretch is highly braided and show, profuse development of anastomosing channels. The change in the trend of the river may possibly due to steepening of the slope of the river.

The entrenched nature of the Yamuna is evidenced by 2-4 km high vertical banks near Delhi and Manjhauli, the vertical banks are seen both along the flood plains as well as the higher alluvial surface. The Yamuna has scoured the top of the higher alluvial surfaces forming a narrow zone of flood plain deposits over it.

Denudational processes are another significant agency engaged in sculpturing the land forms. The closely spaced intersecting joints help in

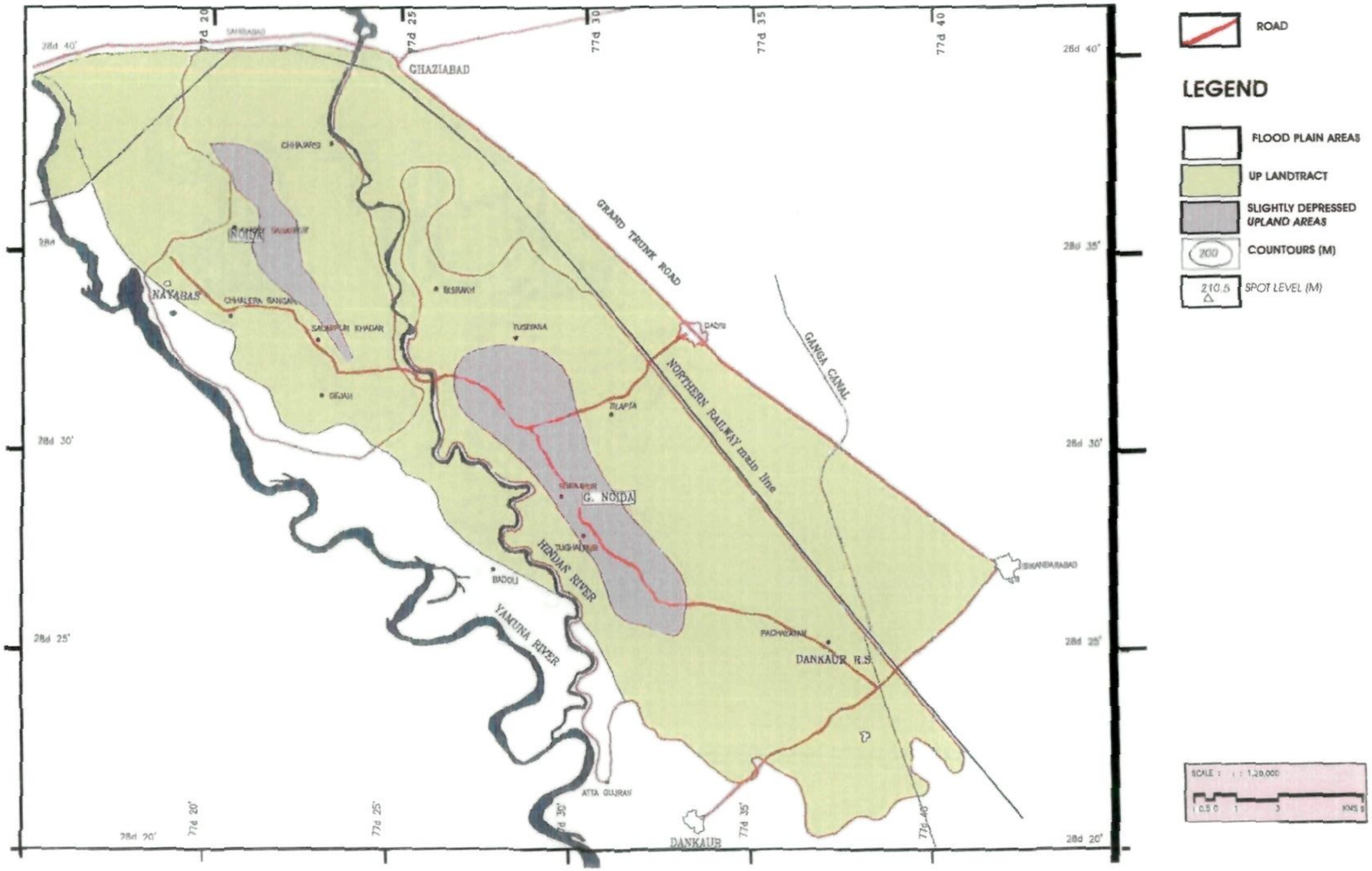

Fig. 2.2. Physiographic map of study area.

the percolation of water resulting in leaching of cementing material, leaving behind a gritty and coarse quartzite. The close spaced joints and weathering through exfoliation and subsequent widening of joints by water action could have resulted in the occurrence of large ferrugenous boulders over the parent outcrop.

The area is situated at the fringes of Aravalli mountain chain which is considered to be a part of relatively stable peninsular shield and belt lies in the moderate intensity zone on the seismic map of India. Tectonic processes have played significant role in shaping the landforms and drainage of the study area. The earthquakes get generated by slipping of alluvium down the floors of Alwar evidently on account of some regional strain. The anamolous widening of Yamuna flood plain and the easterly basement slope at Shahadara is indicative of the occurrence of neotectonism. The westward migration of the Yamuna might have been an associated process.

The Gangetic plain occupies the central position in the Indo-gangetic plain and extends from Delhi ridge in the west to Rajmahal hills in the east It is an active peripheral foreland basin, formed on the underthrusting Indian plate due to thrustfold loading of the Himalayan Orogen. Based on the foreland basin tectonics the Gangetic plain has divided into three zones, the III piedmont zone, central alluvial plain and

Marginal alluvial plain (Fig 2.3).

Geomorphologically, the entire study area has been divided into two broad categories i.e. older alluvium surface and recent flood plain. Older alluvium surface are composed of unconsolidated sediments of considerable thickness brought by river. Various geomorphic features identified like abandoned meanders, channel files, mender scroll, point bar deposits and palaeo channel. (Fig.2.4). Quaternary alluvium is separated by older one on the basis of light coloured due to less decomposed organic matter, quaternary alluvium contain lenticular beds of all grades of sand and gravels.

2.3 Drainage

The study area is drained by the Yamuna river (Fig.2.5) which shows distinct braiding characters as indicated by (i) abundance of anastomosing channels around Chhansa and (ii) presence of numerous point bars and channel bars in the entire stretch of the river in the present area. Yamuna flows in general SSE direction while Hindon river easterly migration is evidenced by palaeochannel and abandoned channels in the west of the river. There are numerous small drains, and distributaries flowing over the area. The river Yamuna, which makes the southwestern boundary mainly, recharges groundwater bodies of the area only during flood period. During the heavy monsoon, the subsurface drainage gets

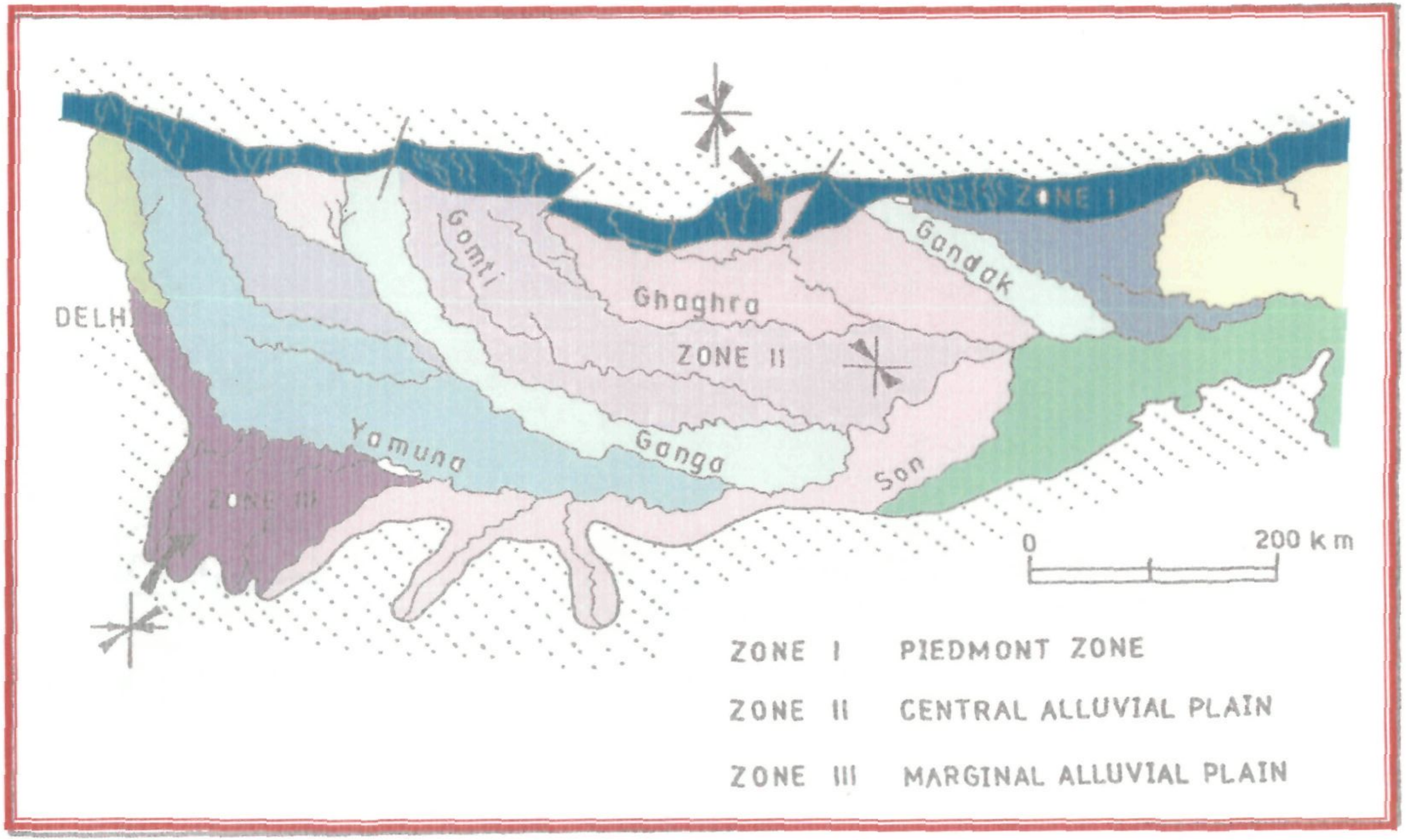

Fig.2.3.Schematic map showing major neotectonic trends, in Indogangatic plains.

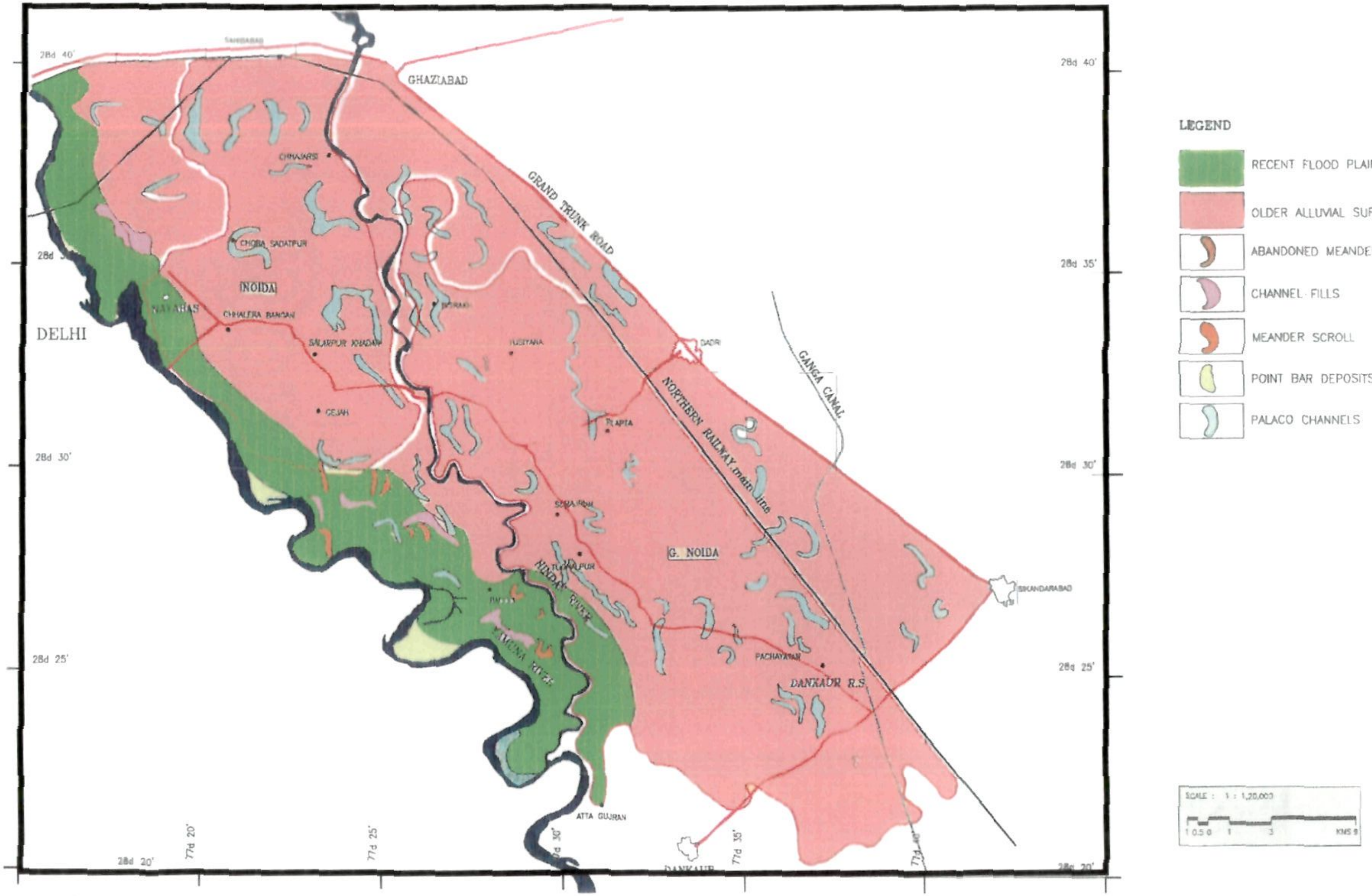

Fig.2.4. Map shows Geomorphological feature of the study area.

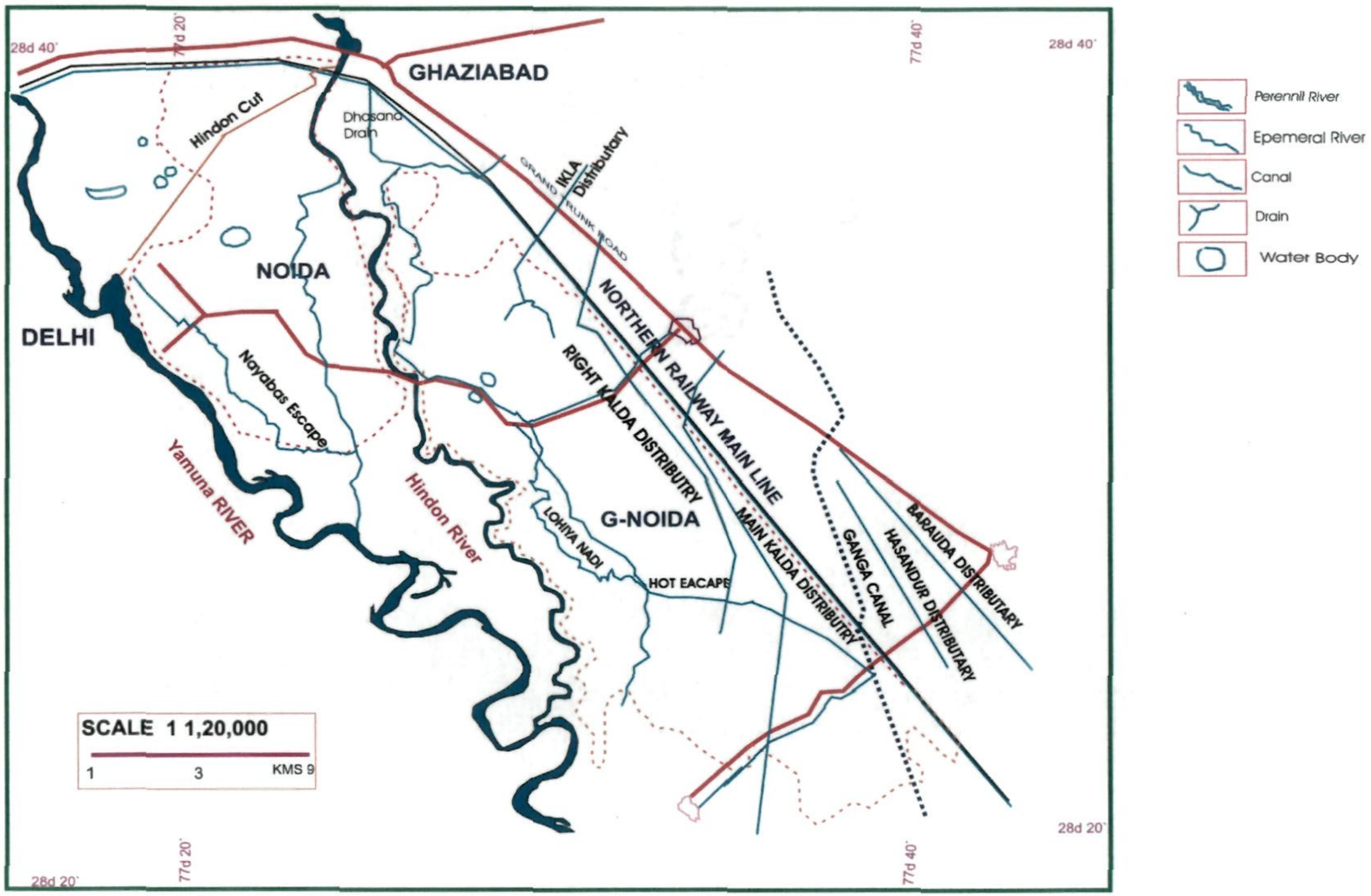

Fig. 2.5. Shows the drainage pattern of basin.

reactivated in such saturated areas causing flooding and inundation in the area. The river Hindon is draining to the central portion of the area. The eastern and southeastern portion is dominated by the presence of canals and drains. Besides these, the surface water bodies are also responsible for the recharge of the aquifers and their concentration is found more in northern portion. The major source of the recharge of the ground water bodies in the upper Ganga canal which flows through eastern end of Greater Noida. Noida does not have any major drainage channel with its limits. One of the depressions serving as basin for a sub catchment is an approximately 125 hectares close to Makenpur in the north near the Hindon cut.

2.4 CLIMATE AND RAINFALL

The area has typical tropical climate with extremes in summer and winter. The summer begins by the end of March and continues upto June, with appreciable heat and dust storms of severe intensity. The mercury shoots upto 44°C or even more during summer and nearly drops below 5° C during winter.

Winter season starts from middle November to the end of February. Severely cold during December to January. The relative humidity is variable being maximum during the month of August and minimum during the month of May. The wind speed being maximum during May to June and minimum during December to January.

2.4.1 Rainfall

The precipitation takes place due to south-west monsoon during the months of July to September and accounts for nearly 80% to 90% of the annual rainfall. The remaining 10 to 20% of rainfall takes place from January to March during winter period. The average annual rainfall in study area is 680.30 mm. Monthly rainfall data of eleven years (1996-2006) in the study area has been summarized in Appendix II-A.

2.4.2 Areal Distribution of Rainfall

In order to understand the areal distribution pattern of annual rainfall. The line graph has been prepared to show the variation of Rainfall (Fig. 2.6). The south-western part of the area receives less rainfall as compared to north-eastern part. The departure and cumulative departure from the mean annual rainfall for study area are presented in Appendix II-B and are shown in Fig. 2.7. The departures show wide variation from the mean, indicating eractic nature of the rainfall whereas cumulative departure end up around the mean annual rainfall reflecting a cumulative compensating effect as far as the quantum of excess and deficient rainfall over a larger period are concerned.

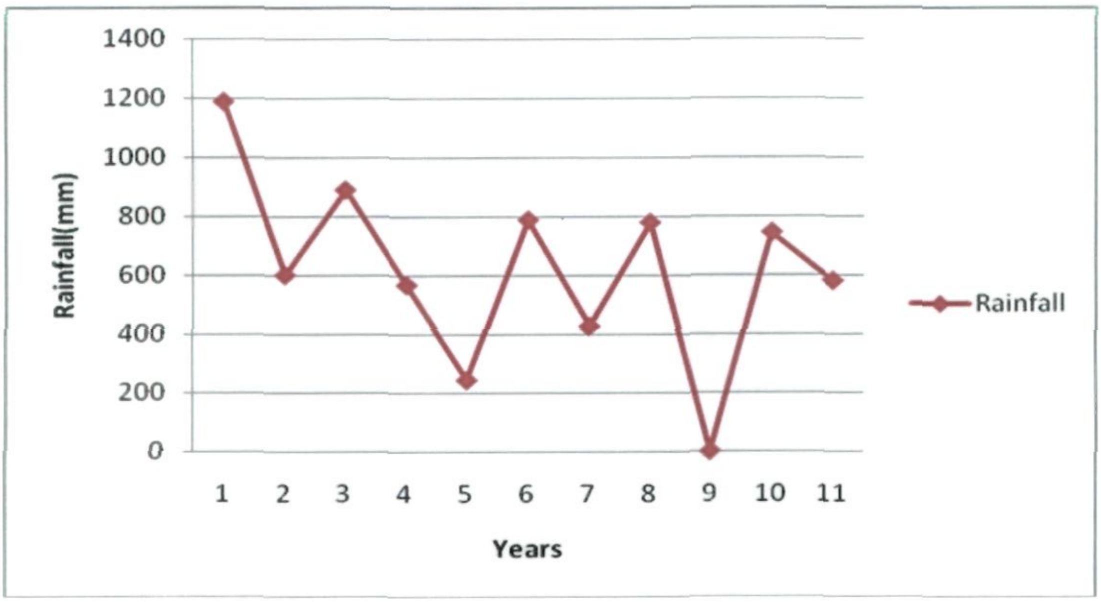

Fig.2.6. The variation in rainfall in years.

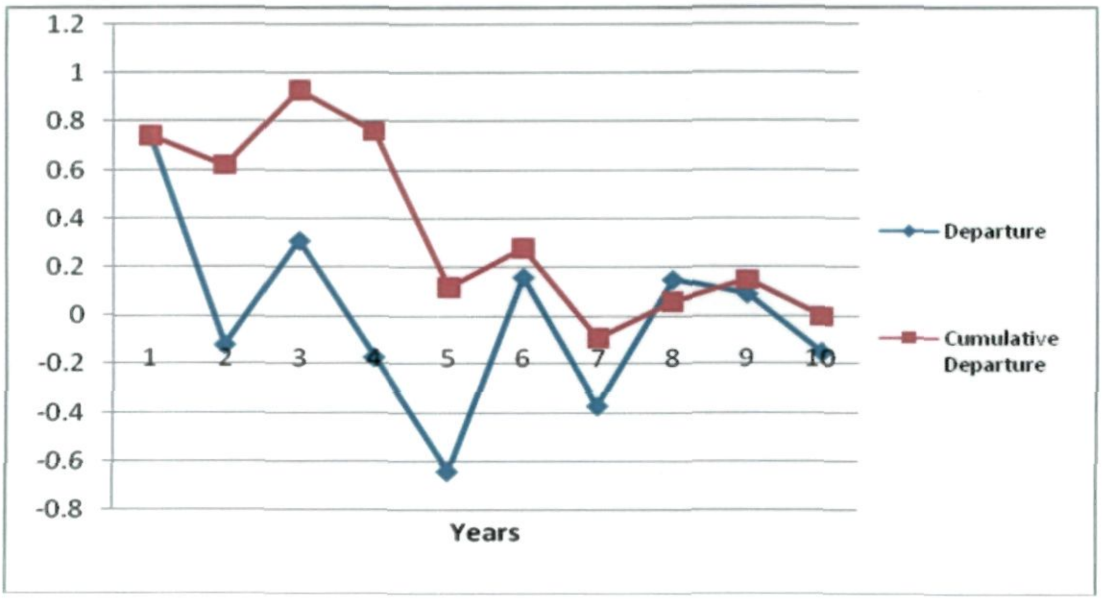

Fig.2.7. Departure and cumulative departure of rainfall Ghaziabad.

2.4.3 Variability of Rainfall

The available average annual rainfall data of the basin from the period 1996 to 2006 have been statistically analysed and results tabulated (Table 2.1), The highest rainfall was recorded (1187 mm) in 1996 and the lowest (243 mm) in year 2000, showing a wide range of variation. The average annual rainfall for the entire study area is 680.3 mm. The standard deviation of rainfall has been calculated data is 247.17.

The coefficient of variation of rainfall in the basin varies from 36.33 which shows that the occurrence of rainfall varies moderately all over the catchment area indicating a significant variability of rainfall in time and space.

Table 2.1: Statistical Analysis of Average Annual Rainfall

Highest rainfall (1996)	118.7mm
Lowest rainfall (2000)	243 mm
Mean (11 years)	680.3 mm
Standard deviation	247.17
Coefficient of variation	36.33%

2.4.4 Drought Analysis

Droughts and floods are the consequences of the variability of rainfall in space and time. The occurrence of drought results in the reduction of stream flow and hence reduction of reservoir and Bank levels, depletion of ground water levels and moisture contents. The drought characteristics and its consequences vary from zone to zone, depending upon hydrological, hydrometeorological and agroclimatological conditions prevailing in the Sub - basin.

The classification of droughts based on the percentage of the negative departure of rainfall from its mean is as follows : (Upadhya et. al 1989).

Percentage of Departure	Type of Drought
0.1-25.0	Mild drought
25.1-50.0	Normal drought
50.1-75.0	Severe drought
75.1-100.0	Most severe/rare drought

The results show that the average frequency of mild drought is 30.00%, normal drought is 10.00%. The frequency of severe drought during a period from 1996 to 2006 is 10%.

Table 2.2: Shows Drought analysis in Sub-basin.

Type of drought	Years	Frequency of occurrence
Mild drought (0-25%)	1997,1999,2006	30.0%
Normal drought (25-50%)	2000	10.0%
Severe drought (50-100%)	2000	10.0%

2.5 LANDUSE PATTERN

Noida and Ghaziabad districts are parts of Ganga–Yamuna doab located adjacent to Union Territory of Delhi. The basin is rich in the development of agriculture as well as in industrial domain. It covers an area of about 2596 sq.km. The total population of Noida and Ghaziabad as per 2004 census has been estimated about 20.5 lakh respectively. Each type of landuse is influenced by the use of water in a particular form.

Table 2.3: Shows Land use pattern.

Utilization	Area (hectares)
Forest	2,556
Cultivated wasteland	7,568
Fallow land	17,541
Pastures	521
Grooves	1,315
Miscellaneous use other than agriculture	36,295
User and unsuitable for agriculture	9,252
Net area under agriculture	18,4407

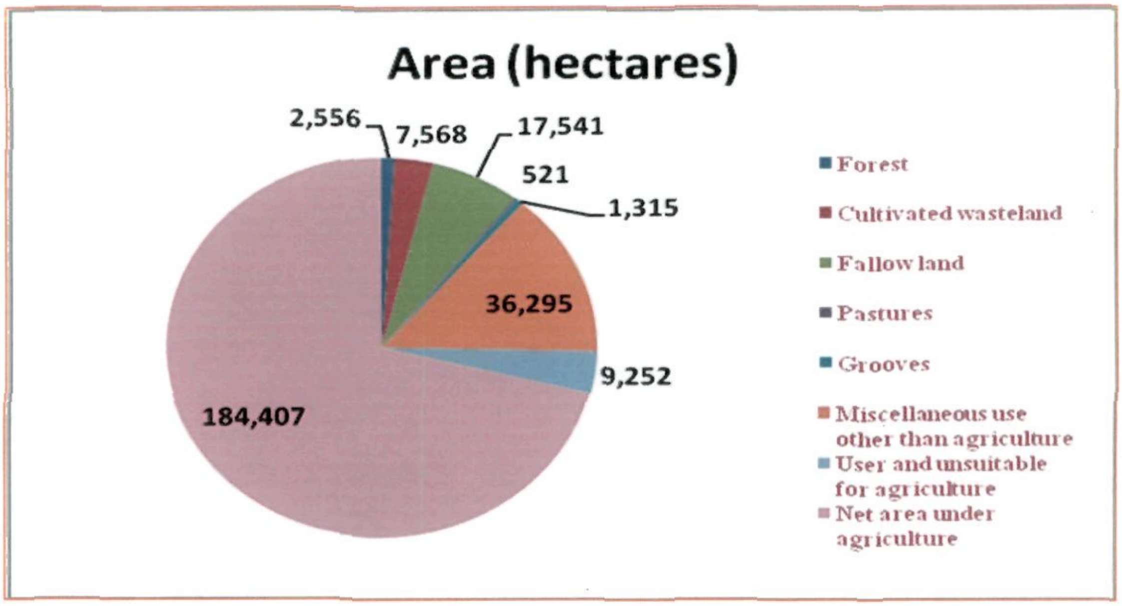

Fig. 2.9. Land use pattern in the area.

The total area considered for land utilization in study area is estimated as 2,59,455 hectare as per the statistical records available for the year 2006. On the perusal of Table 2.3, it is concluded that 71% of the area is under agriculture and 14% is under miscellaneous use. About 9.6% of the total area is presently fallow and cultivable waste, which need to be brought under agricultural and industrial uses (Fig.2.9).

The entire area is under cultivation of Rabi and Kharif, therefore, natural vegetable growth is low and sparse. Kharif crops dominate the area. The main crops grown in the area are wheat, sugarcane, maize, Jawar and bajra. Paddy is grown only in the limited area. The changes in categories of land use / land cover during the period 2000 to 2006 can be depicted in Fig.2.8. The changes have been taken place in following manner:

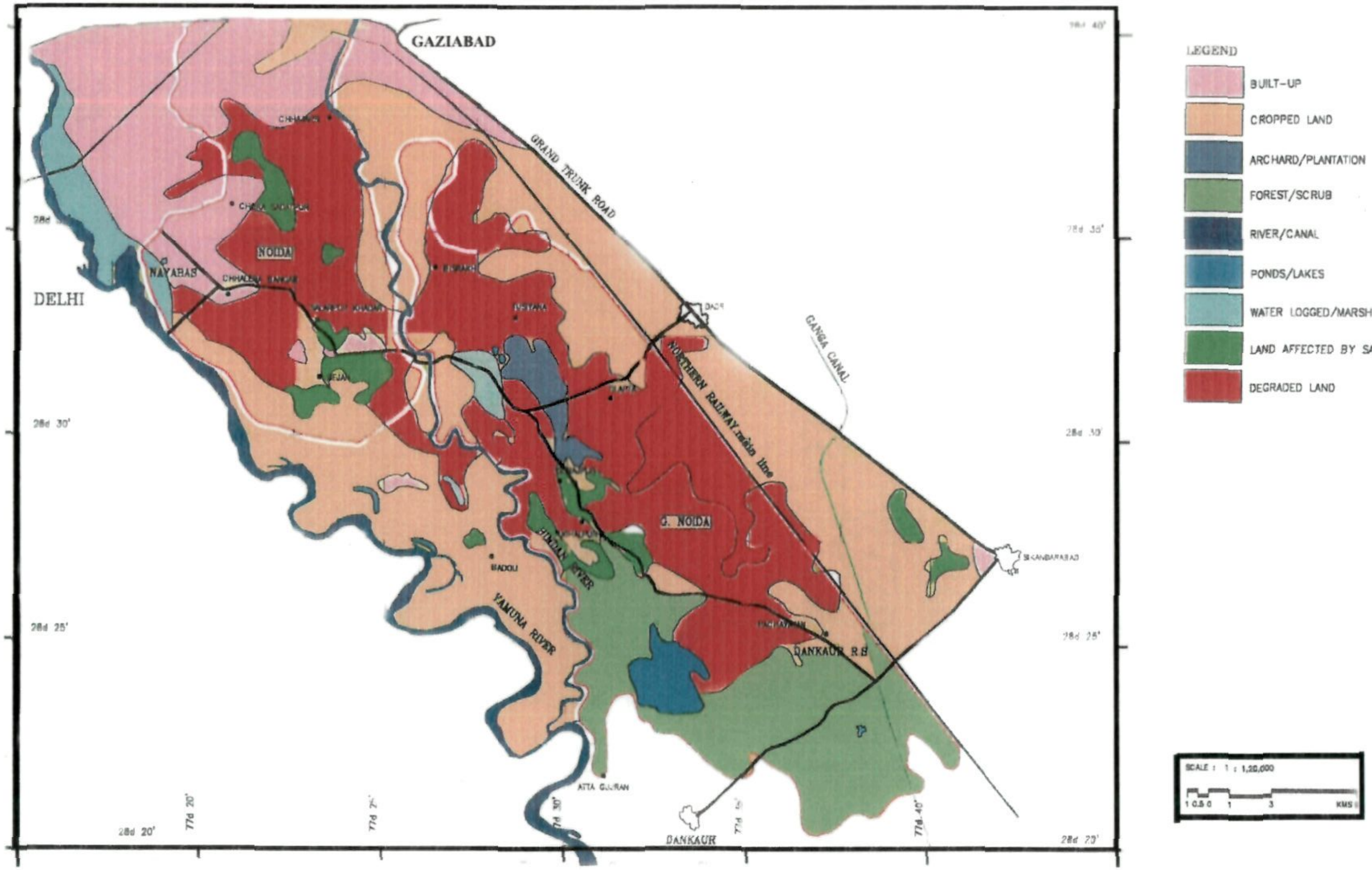

Fig. 2.8. Land use and land cover map of Yamuna- Hindon Basin

1. Cropped land to plantation.
2. Cropped land to built- up land.
3. Cropped land to salt affected land.
4. Salt affected land to built up.
5. Water logged to salt affected land.
6. Waterlogged to cropped land.
7. Forest to built up land.

2.6 Classification of Soil

The Indo-Gangetic Plains are formed by the periodic deposition of silt brought by rivers abounds in alluvial soil. The alluvial tracks of Ganga-Yamuna interfluve have got very fertile soil. The study area is characterized by three types of soils viz. (i) Loam (ii) Clay Loam and (iii) Sandy Loam (as per Geological Survey of India, 2003). The distribution of the three soil types is shown in Fig. 2.10.

2.6.1 Loam Soil

This type of soil is found in an elongated track between Eastern Yamuna and Hindon river. This track is having excellent cultivation. This is the most common type of soil in the area. Generally, the surface soil to a depth of 20-25 cm is well drained soil and contains loose loam that can easily be ploughed and cultivated. The soils are more leached than the other soil of the area. The percentage of lime content is low. The

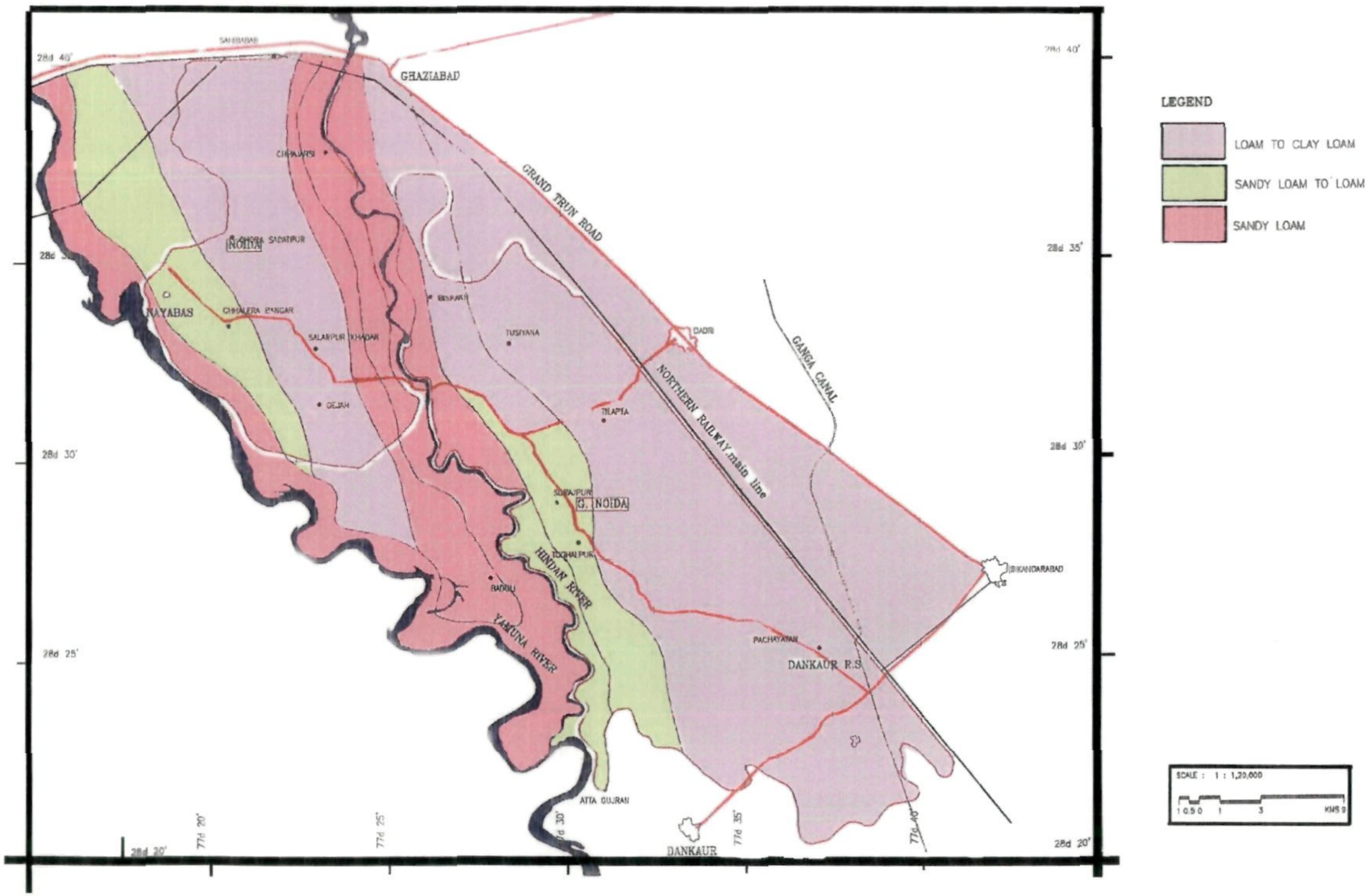

Fig.2.10. Map shows the soil charcterctics of study area.

calcareous nodules occur almost everywhere in the sub-soil. The pH ranges between 6.2 to 6.8.

2.6.2 Clay Loam Soil

Clay loam soil has striking geographical attributes as it occurs all along the Yamuna river. Towards the east it occurs between Eastern Yamuna Canal. The tract is underlain by thick pan of calc concretions occurring in mild cases in the form of nodules which at places cement together forming a stiff impermeable belt in the bottom layers. Due to poor drainage, the soluble sodium salts are deposited on the surface in the form of salt efflorescence (salt peter) which is locally known as *Reh.* The pH value of the soil ranges from 7 to 9.

2.6.3 Sandy Loam Soil

This type of soil is found in a narrow elongated tract, along with the Hindon river, a left over channel of Yamuna river. Generally, the soils are alkaline in reaction with a pH value above 8. The soil profile consists of numerous immature stratified layers of younger soils which are deposited over one another during the flood periods of river Yamuna. These soils have fewer reserves of lime, magnesia and iron. The presence of lime saves the soil from becoming completely salinized.

The development of soil in the area can be ascribed to different erosional and depositional agencies. Different morphological units have been bestowed with different types of soils. The alluvium brought by the Yamuna spreads all over the area. The alluvial soil of the study area has been divided into two broad divisions, the older alluvium and younger alluvium.

The soils range from pure sand to stiff clay, with all combinations of the two extreme litho units. The pure sand is called Bhur and is commonly found close to the Yamuna river in geomorphic units namely sand dunes and natural levees. The water holding capacity of these soils is low. They are deficient in organic matter, calcium and clay. The surface soil is compact silty clay or sandy clay which is calcareous in nature at certain places. The Bhangar soil occupies the level of plains above the general flood limits of the river. The soils vary from clayey loam to sandy loam depending on the land form and the drainage of the region.

Sandy loam occurs in the western and southern part of the area but it becomes silty in northern part. The soils are sandy in texture and brown or reddish brown in colour. The western part of Yamuna flood plains show development of light brownish grey silt or sand over the surface. Grey silt or sand is incoherent of light brownish grey silt or sand over the surface. Grey silt or sand is incoherent sand is confined in the vicinity of fluvial features while the light brownish grey silt and clay developed over terrace surfaces which are not always flooded.

The soil at place is characterized by the presence of impure calcareous concretions known as "kankar" and is found at different depths. The presence of kankar in the soil profile causes water logging and gives rise to alkaline soil. Alkalinity and bad physical character of the soils render them unfit for normal agricultural uses.

CHAPTER-III

GEOLOGY

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3.1 GENERAL GEOLOGY:

India is divisible into three distinct physiographic units viz., the Peninsular shield, the Himalayas and the Indo-Gangetic plain (Fig. 3.1). The Indo-Gangetic Plain in the extensive alluvial plain of the Ganga, Indus and Brahmaputra rivers and their tributaries and separates the Himalayan range from peninsular India.

Peninsular shield is composed of geologically ancient rocks of diverse origin, most of which have undergone much crushing and metamorphism. Structurally, the Peninsula was supposed to represent a stable block of the earth crust which has remained unaffected by mountain building movement since the close of Precambrian era, however in recent months doubts have been expressed about its stability.

The Himalayas is a region of folded and over-thrust mountain chains of about 65 million years old. Their curvilinear structure is very striking. They consist mainly of circular arcs which are convex towards Peninsula i.e. towards the rigid crust against which they appear to have been thrust (Krishnan, 1968). Though, the Extra-Peninsula composed of very old rocks, it is predominantly a region in which sediments were laid down in a continuously deepening depression between two plates from the Cambrian to early Tertiary age. The rivers of the Himalayas are youthful and are actively eroding their beds in precipitous courses and

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Apologies for
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Hope it hasn't
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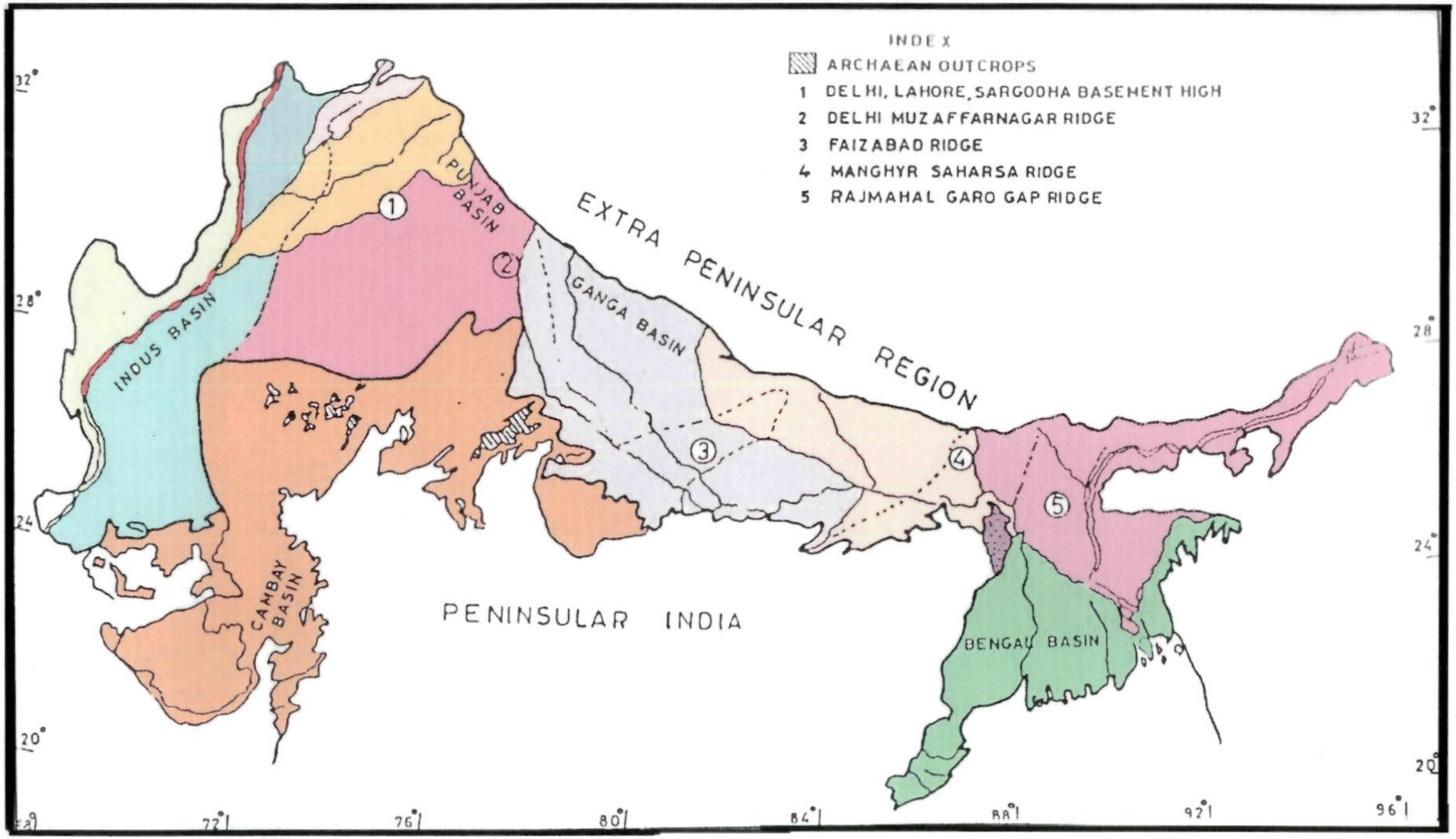

Fig. 3.1. Map of Indo-Gangetic plain indicating the broad divisions.

carving out deep and steep sided gorges and flow across it in order to join the plain.

The Indo-gangetic plains in which the study area lies, are broad, monotonous, level expanses built up of Quaternary alluvium was brought down by the rivers draining the Himalayas and which forms the major unit in the geology of the Indian subcontinent. It includes the great alluvial tract of the Ganges, Brahamputra and Indus covering an area of 85000 sq. kms. (Krishnan, 1968). The rivers of the Indogangetic plain flow sluggishly towards the Bay of Bengal or Arabian Sea.

Earlier, there has been much speculation regarding the sub-surface geology and tectonic origin of the vast depression of Gangetic alluvial plain. The plain line deflection and gravity data obtained by Survey of India, many years ago, were too meagre to give any concrete indications of the subsurface geology. The tubewells drilled for groundwater did not go down beyond a depth of 600 metres and the data on solid geology of the plains was lacking entirely. However, with the advent of geophysical exploration in these plains, a fairly large volume of data indicating the nature of sub-surface geology has been obtained which was further substantiated by number of deep exploratory wells drilled in these plain by *Oil and Natural Gas Commission (1999).*

Although, the Indo-Gangetic plain appears as one vast stretch from one end to other, geologists have the opinion, that the floor of this plain is not an even but there are hidden ridges and depression which lies under the alluvium *(Rao, 1973)*. Ridges refer to the linear aeromagnetic anomalies, which are structural features of the Ganga plains, might have formed important topographic divides at the time of Vindhyan deposition, but subsequently peneplained, and the overlying Siwaliks occur with nearly uniform thickness across the ridges.

Geologists believe that below the alluvial covering, there is an appreciable diversity in the constituents of rock formation. Estimate of thickness of the Ganga alluvium have been ranged from about 15 kms *(Burrad, 1951)* to 4.5 kms *(Oldham, 1917)*. Further, *Wadia (1966)* and *Krishnan (1968, 1982)* have been pointed out that beneath the alluvium, the sedimentary formation of palaeozoic, mesozoic and tertiary ages may be found, which is supported by reported occurrance of upper proterozic Vindhyan in Ujhani and *Aligarh*. At *Kanpur* and *Ujhani,* however, Bundelkhand granite was encountered at a depth of 504 m and 2161 m b.g.l. respectively.

The most important basic data regarding the basement configuration and sedimentary basin of the Indo-Gangetic plains are provided by *Agcos (1957)*. Basement depth contours for the whole of

Indo-Gangetic plain have also been counted by aeromagnetic data which shows increasing thickness of sediments along the foot hills of the Himalayas. The maximum depth to the basement as indicated in Seismic surveys is about 6 kms along the northern boundary.

The Indo-Gangetic plain can broadly be divided into the following five basins from west to east (Fig. 3.1):

1. Indus basin of Pakistan
2. The Punjab basin in the Punjab
3. Brahmaputra basin in Assam
4. Bengal basin in West Bengal and Bangladesh
5. Ganga basin in U.P and Bihar

3.1.1 The Indus Basin:

Except for the area under Thar desert in Rajasthan, a greater part of the Indus basin lies In Pakistan. It is filled up by sediments which started in early Paleozoic to quaternary and possibly also by Vindhyans remnants which are found in western Rajasthan (Krishnan, 1968). This basin is 6000 m deep in Sind. A large thickness of Tertiary and Mesozoic sediments have been met under the alluvium. This thick marine sequence has thinned out towards Rajasthan platform.

3.1.2 The Punjab Plain:

The Achaean basement rocks occurring under moderate thickness of alluvium in Lahore-Sargodha area separate the Indus basin in the west from the Punjab depression in the east. The Seismic Survey by the Oil and Natural Gas Commission (Datta et al., 1964) has indicated that the basement surface as well as sediments below the alluvium gently dip towards the foothills due to west. However, the basement becomes deep as foothills are reached with corresponding increase in the thickness of sediments. The maximum depth of basement is 4.5 kms. (Datta et al., 1964).

3.1.3 The Brahmaputra Basin of Assam:

The Brahmaputra basin lies between the Himalayan foothills and Shillong-Mikir hills. In this basin the sediments attain appreciable thickness as the basement becomes deeper and deeper close to the Himalayan foothills. However, the basement is shallowest towards the Mikir hills.

3.1.4 The Ganga Basin:

The Ganga basin, Occupying an area of about 250,000 sq.km. falls within Long. 77° E and 88° E and Lat. 24° N and 30°N. It includes more than half of the total area of Indo-Gangetic plain. This basin comprises a great long sedimentary area, flat and monotonous which is drained by the river Ganga, and its various tributaries. The western margin of the basin is bounded by Delhi-Haridwar ridge with middle Proterozoic rocks and in the east by the Archean Monghyr-Saharsa ridge. To the north, the Ganga basin is limited by outermost Siwalik foothills of the Himalayas bounded by the Himalayan Frontal fault which runs parallel to the Himalayas from west to east. Along the southern fringe of the basin, Bundelkhand granite-gneiss, Delhi Super Group and the Upper Vindhyan Group of rocks are exposed. The Ganga basin represents a large scale regional depression on the northern margin of the Indian platforms and is considered as super order crustal structure of negative character most probably forming a northerly continuation of Vindhyan Syncline *(Shastri, 1971)* (Fig. 3.2 & 3.3).

3.2 ORIGIN OF THE GANGA BASIN AND STRATIGRAPHY OF THE STUDY AREA:

There has been more speculation regarding the sub-surface geology and tectonic origin of the vast depression of the Gangetic alluvial plain which came into existence in the Pleistocene period. This land lying in front of the newly risen Himalayas, formed a depression, which was rapidly being filled up by sediments coming from the rising Himalayas and the Peninsula. Various hypothesis have been put forward to explain the geological evolution of this plain. Suess (1904-1924) has

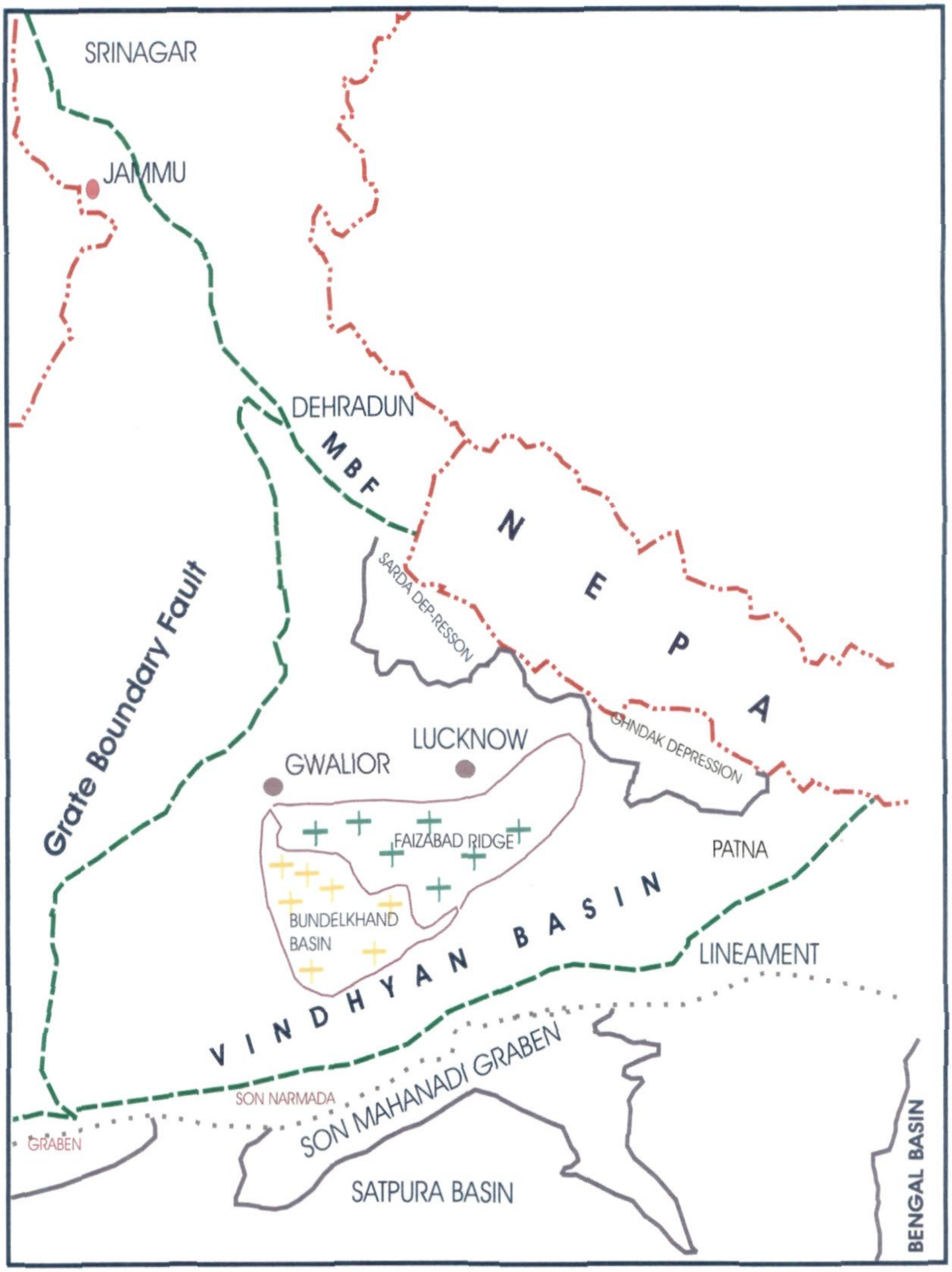

Fig.3.2. Major tectonic features of the Ganga basin.

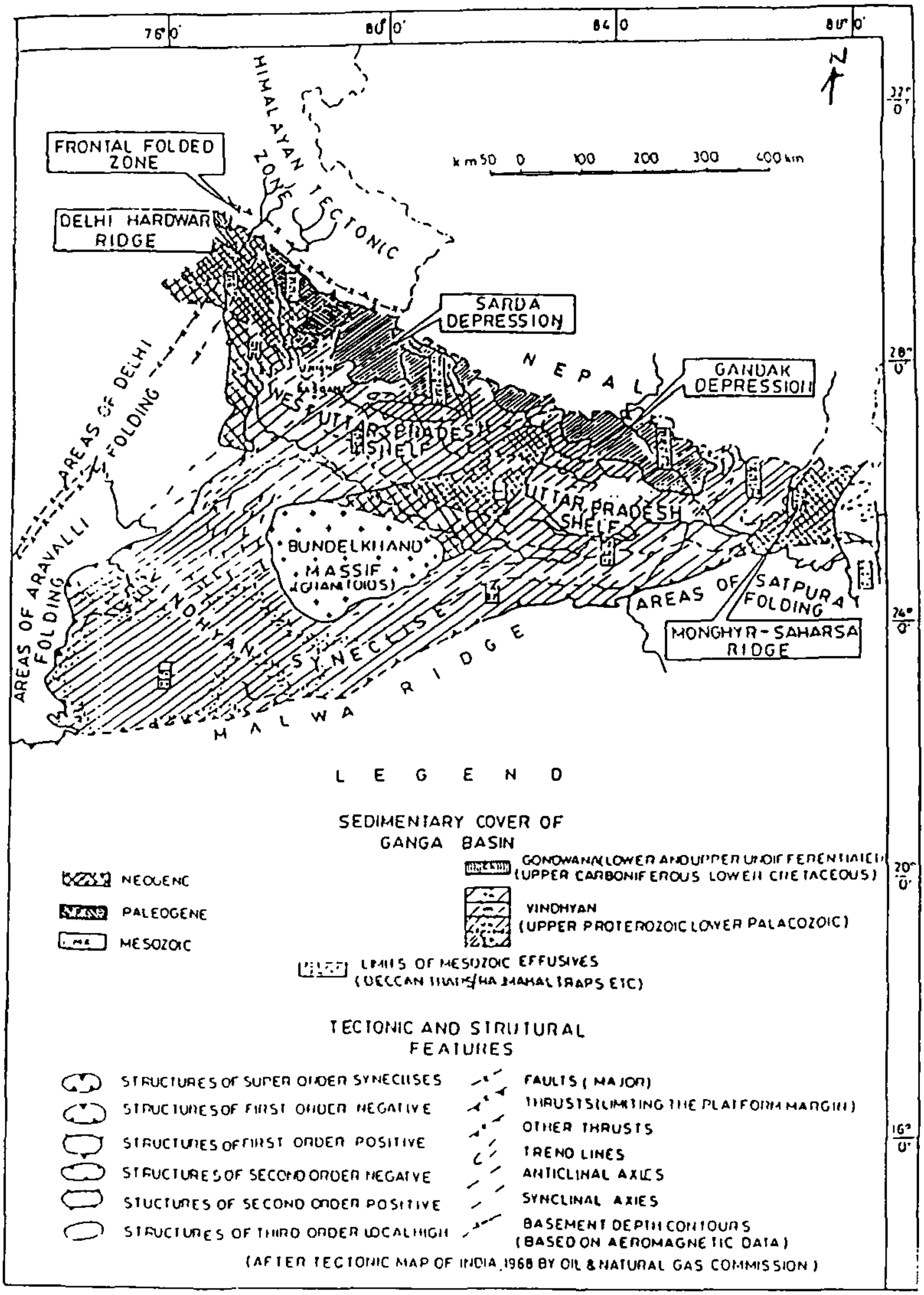

Fig. 3.3 Tectonic map of Ganga basin and adjoining areas.

suggested that it is a 'fore-deep' formed in front of the high crust waves of the Himalayas as they were checked in their southward advance by the inflexible solid land mass of the Peninsula. On the basis of physical and geodetic considerations Burrad (1915) considered that the Indo-Gangetic Plain occupies 'rift-valley', a portion of the earth's surface sunk in a huge crack in the sub-crust, between parallel faults on its two sides. This rift extends from the surface for down into the crust about 32 kms. deep and is subsequently filled up by alluvium. This view has got few geological facts in its support but is not adopted by geologists, who believe that the Indo-Gangetic depression is a true 'fore-deep', a down-warp of the Himalayan foreland, of variable depth, converted into flat plains by the simple process of alluviation. In this view, a vigorous sedimentation took place and this deposition kept pace with subsidence giving rise to this tectonic trough of India *(Valdiya, 1981).*

According to *Krishnan (1982)* the Indo-Gangetic alluvial trough is a region whose origin and structure are closely connected with the formation of the Himalayas. He suggested that the Gangetic plains owe its origin to a sag or depression which has been formed by buckling down of the crust in obedience to pressure exerted on the borders of the Peninsula by compressive forces. *Valdiya (1982)* interpreted it is a resultant effect of sagging of the northern flank of platform around the

Bundelkhand shield following the main episode of the Himalayan orogeny. The depression was filled up with sediments brought by rivers flowing from the Himalayas and the Peninsula *(Sharma and Coutinho, 1980).*

Dickenson (1974) has emphasized that the major sedimentary basins developed between fore-thrust belts and the craton, over which the mountain belt is thrust. Miall (1981) and Bally (1981) call these basins fore-land rather than fore-deeps. Fore-land basins are asymmetrical, and deepest near to the fold thrust belt they migrate towards the fore-land and have resulted from downward flexturing of the lithosphere by over-riding fold thrust belt *(Beaumount, 1981).*

Dickenson (1974) considers the Indo-Gangetic trough as the most impressive, present day, peripheral fore-land basin formed as the result of continent to continent collision between Indian and Asian plates. The basin has developed on the under thrust Indian plate and due to loading of thrust sheets in Himalayas causing a viscoelastic flexture in the crust allowing sediments to accumulate under fluvial process.

According to *Singh (1989)* the Gangetic plain is a part of active foreland basin (peripheral type) developed on the under thrusting Indian plate, in response to the thrust fold belt loading in the Himalayas. Further, *Singh and Ghosh (1988)* an *Singh (1989)* opined that during thrust-fold loading tectonics in the Himalaya, the Son-Narmada lineament much to the south of the foreland basin was reactivated, causing uplift of Bundelkhand-Vindhyan plateau and development of northerly slope (Fig. 3.4).

The rate of subsidence of the old, rigid and old crust of Indian shield was also low and sediment input by rivers high, so that no marine transgression of Neogene-quaternary time could enter into this foreland basin. The deep drilling data of the O.N.G.C. are contrary to this view, as the deposits of Neogene sediments are reported from all over the Ganga basin *(Sastri, 1971; Rao, 1973)*.

The exact thickness of the alluvium has not been ascertained, but recent gravity, magnetic and seismic explorations show that it is variable from less than 1000 to over 2000 meters. Geologists differ in their estimates about the thickness of the alluvial deposits. However, the drilling carried out by O.N.G.C. (Oil and Natural Gas Commission) have yielded stratigraphic informations pertaining to the sub-surface geological framework which indicates the presence of upper Vindhyans below the Siwaliks are as follows:

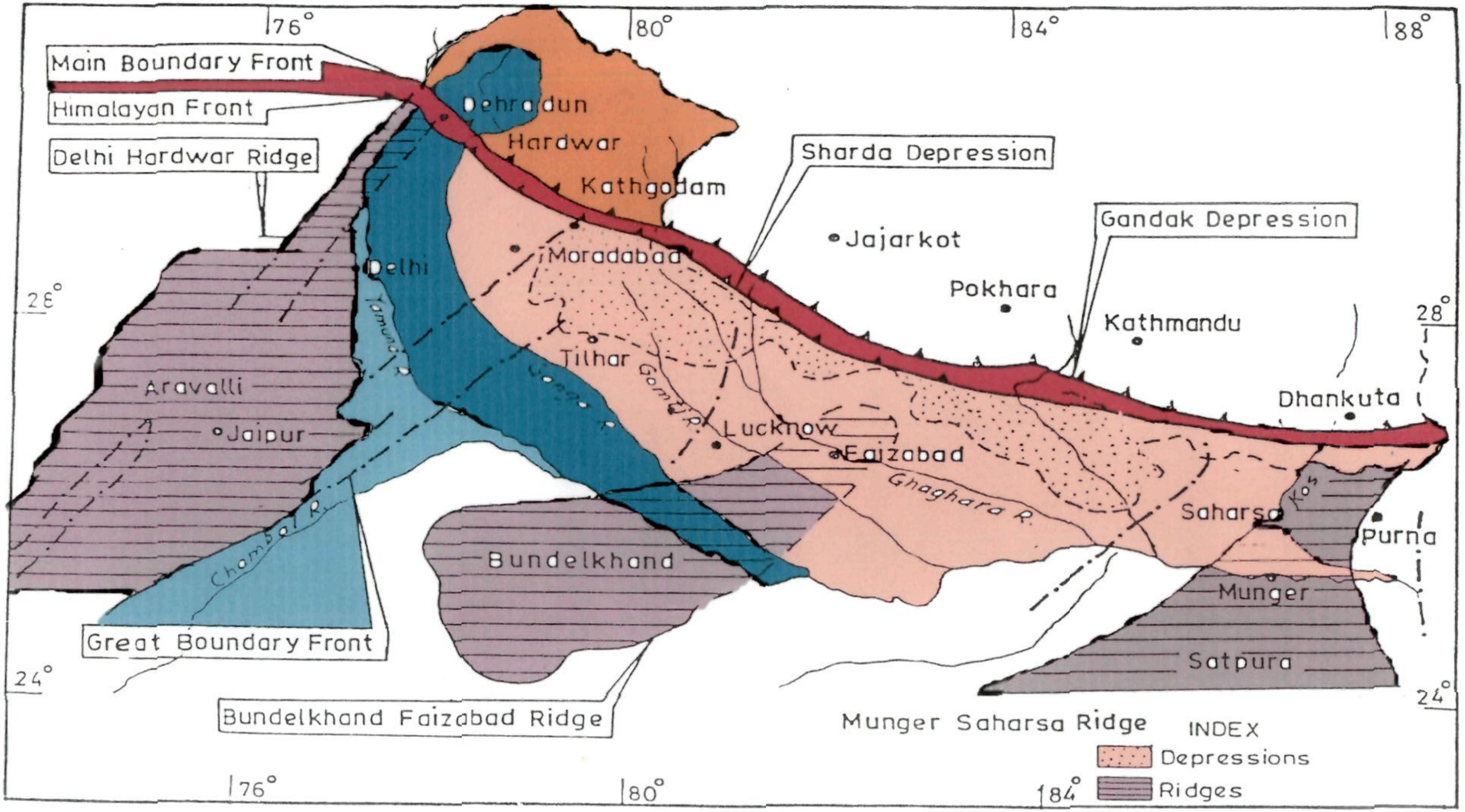

Fig. 3.4. Shows the major structure of Ganga basin.

Table 3.1: Vindhyan formation in Ganga basin

Wells	Depth interval (metres)	Thickness	Age
Kasganj structural	620 – 1250	630	Upper Vindhyan
Ujhani deep well	1010 – 2062	1052	Upper Vindhyan
Tilhar	1718 – 2225	507	Upper Vindhyan
Puranpur	3174 – 4235	1061	Upper Vindhyan

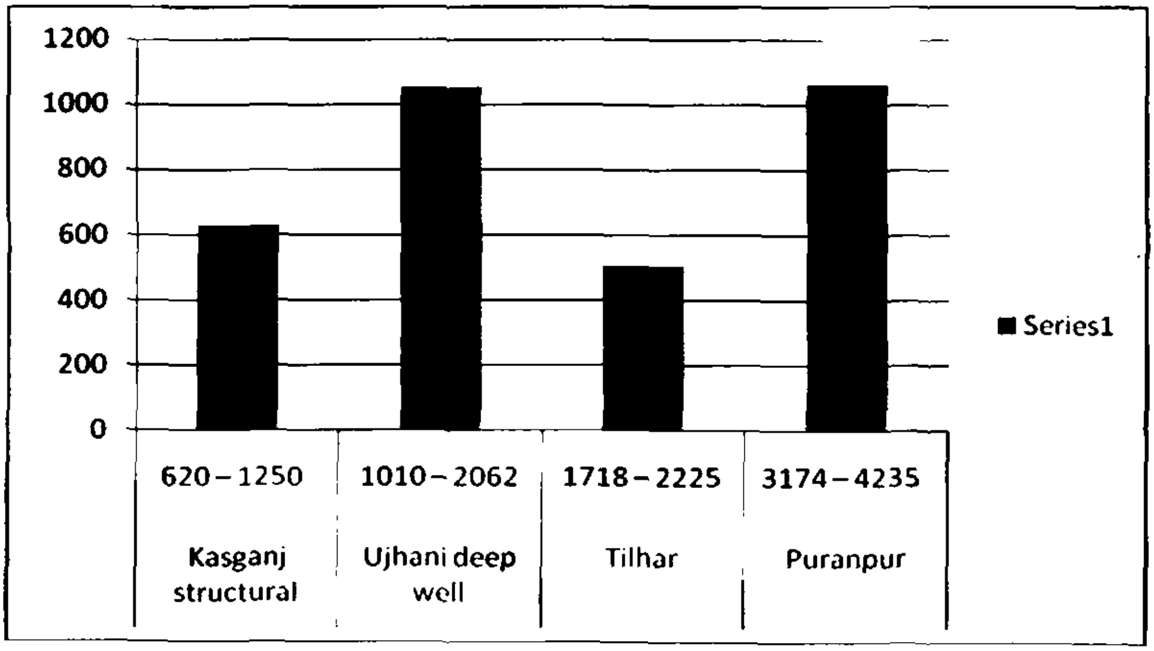

Fig.3.5: Bar diagram shows the Vindhyan formation in Ganga basin.

On the west of Yamuna river Noida and Ghaziabad, the upper Vindhyans have been encountered at different places during the exploratory drilling operations by Central Ground Water Board (Dubey, et.al 1992). The bed rock, the upper Bhandar Sand stone touched at a depth of 286.62 mt below the ground surface.

Stratigraphic Sequence: (Heron 1992):

Quaternary Alluvium	Alternate beds of sand and clay with occasional interbeds of calc-concretions (kankar)
----------Unconformity----------	
Upper Siwaliks Middle Siwaliks (Neogenes)	Coarse to medium sandstone with variegated clay stone and occasional carbonaceous streaks.
----------Unconformity----------	
Upper Vindhyan (Upper Proterozoic)	Upper Bhander sandstones Red shale Reddish brown argillaceous Limestone Greenish-grey dolomitic Limestone
----------Unconformity----------	
(Upper Achaean)	Bundelkhand granite (Basement)

The Bundelkhand granite which is a big batholithic mass extends across the Ganga basin which further extends towards the Himalayan foothills. It underwent structural dislocation wherein the deposition of upper Vindhyan group of rocks took place. Thereafter, it underwent erosion and peneplanation for about 500 million years, and then the deposition of the Siwaliks took place. However, in the study area Siwaliks rocks were not encountered anywhere in Ghaziabad district. With the formation of the Ganga depression, it became the site of deposition, where huge sediments were contributed by the newly risen Himalayas and the rivers emerging from the northern fringe of the

Peninsula leading to the healing up of the depression and giving thereby the present configuration of the Ganga basin.

3.3 ORIGIN OF INDO-GANGATIC ALLUVIUM:

The alluvial tract is of the nature of a synclinal basin formed with the elevation of Himalaya to its north. Sues (1904-1924) considered it as a fore deep formed infront of the high crust waves of the Himalayan as they were checked in their southward advance by the inflexible solid land mass of the Peninsula. According to Krishnan (1968). Indo-gangatic trough is a region formed by buckling down of the crust due to pressure exerted on the borders of the Peninsula by compressive forces. Valdiya (1976) interpreted it is a result of sagging of the northern flank of the platform around the Bundelkhand shield following the main episode of the Himalayan orogeny.

The major basisn of Indo-gangetic plain include Ganga basin, Bengal basin, Brahmaputra basin, Punjab basin and Indus basin. The Ganga basin in which the investigation has been carried out, occupies of 250,000 sq.km. a covering more than half of the total area of the plain. The basin is drained by Ganga river and its tributaries including Yamuna which flows through the study area. The sediments of the basin comprise sand, silt, and clay with occasional ground beds and lenses of peaty organic matter. The older alluvium called 'Bhangar' is dark coloured and generally rich in concentration and module of impure calcium carbonate (Kankar), the newer alluvium called 'khadar' is light coloured and poor in calcareous matter with lenticular beds.

3.4 REGIONAL GEOLOGICAL SETUP:

Geologically the area under investigation are characterized by the presence of thick pile of Quaternary alluvial deposits laid down by the action of river Yamuna. These Quaternary deposits of recent to sub – recent age are underlain by the rocks of Delhi Super Group *(Chopra S, 1990).* Younger alluvium is separated by older one on the basis of darker tone, smooth texture, intense cultivation, thick forestation and association with river. The Delhi super group which comprised Ajabgarh and Alwar groups was intruded by Erinopura granite covering sedimentary formation into the present Delhi quartzite through metamorphism. Much after covered by the quaternary alluvium.

The study area is the part of great alluvial tract of the Indo- Gangetic alluvial plain. The Indo-Gangetic plain is supposed to be one of the best ground water reservoirs of the country. The alluvium consists of the older and newer alluvium of Pleistocene to recent age. The deposits are derived from the denudation and erosion of sedimentary and metamorphic rocks. The turbulent Himalayan Rivers brought down the sediments particularly during the flood period. (Fig.3.6).

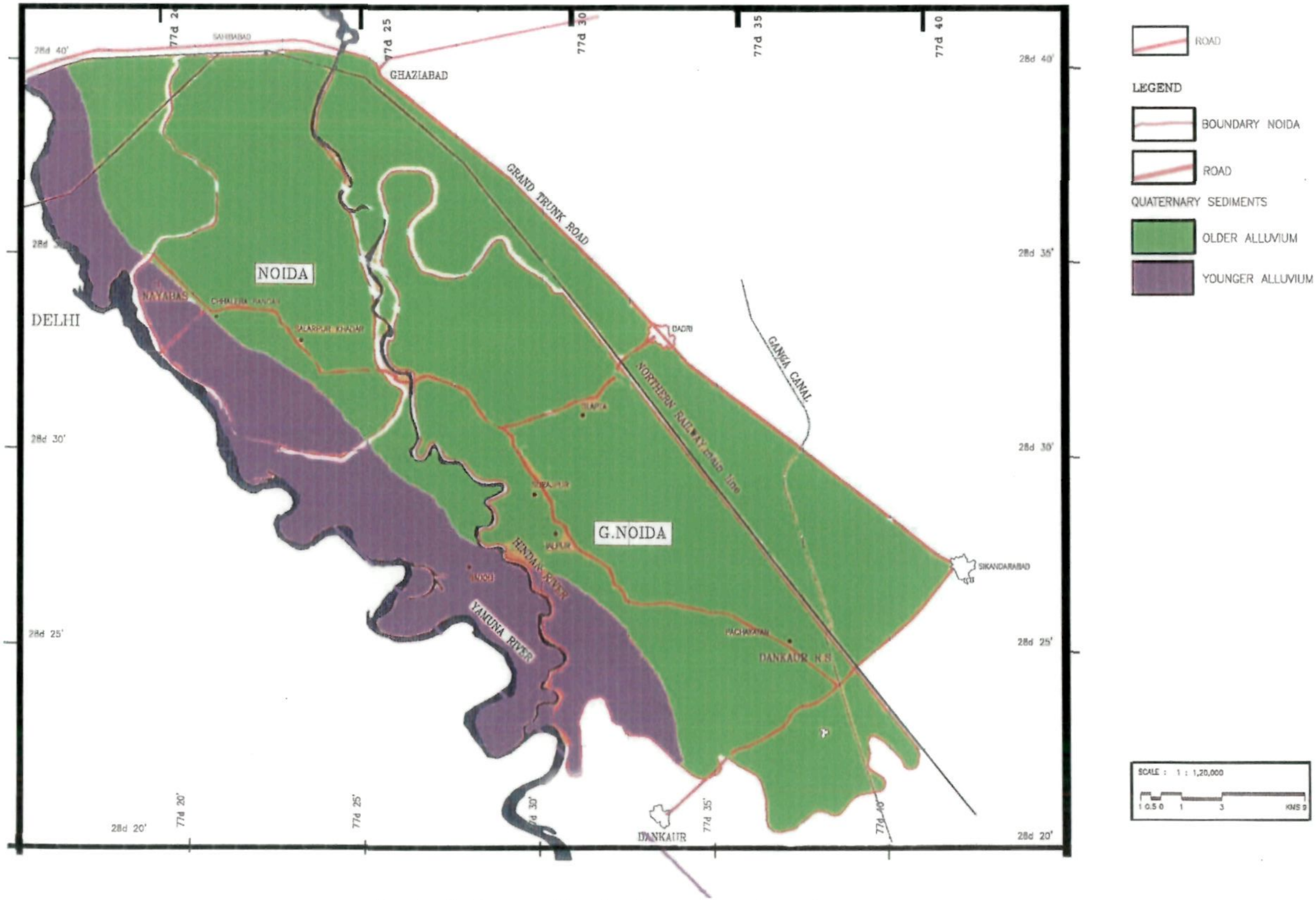

Fig.3.6. Shows Geological map of study area.

The alluvial deposits consist of clay, silt, sand and occasional beds of gravel. The alluvium is generally rich in calcium carbonate locally referred to as Kankar . Kankar is formed when the ground water saturated with calcium carbonate is brought down due to seasonal fluctuation of water table and water rises to near the surface due to capillary action. Because of physiochemical condition, experienced by the saturated solution, calcium carbonate gets precipitated and deposited just below the soil as nodules of carbonates knows as Kankar. The older alluvium is rather dark, whereas the newer alluvium is light coloured due to less decomposed organic matter, these alluvium of quaternary age contain lenticular beds of all grades of sand and gravels in both shallow unconfined and semi- confined beds of this area.

Overlying unconformably the folded and faulted Precambrian Alwar quartzite are deposits of alluvium of Quarternary age over a major part of the area. The alluvial sediments comprise sequence of clay, silt, different grades of sand, gravel and kankar (calcareous nodules) in varying proportions. The borehole records suggest a maximum thickness of atleast 150 mt for this formation at Noida and about 500 to 600 mt at Ghaziabad. The deposits are river laid, lenticular in shape with thickness increases towards east and southeast.

The older alluvium, generally occupying the relatively higher grades is made up of massive beds of clay of a pale reddish brown colour, very often yellowish with kankar disseminated throughout. On the other hand the newer alluvium confining mainly to the river valleys is light coloured, poor in calcareous matter and is made up of coarse gravels, sandy clay and sand in the proximity of the river channels, and fine silt in the flatter distal parts of the river plains.

The lithologs of the tubewells drilled in study area show that the alluvium within 40 to 50 m depth comprises mainly of sand with clay and kankar intercalations and is predominantly clayey at deeper levels. Gravel and calcium carbonate concretions are quite common at shallow depth as thin beds and lenses or as nodules disseminated in clay. A hiatus in sedimentation or change in climatic conditions may be responsible for the kankar development in different horizons. The clay sand thickness ratio down to the depth range of 70 – 80 m showed normal distribution. However, at greater depth a different distribution suggests changes in the depositional regime. The Quarternary alluvial deposits are considered to be fluvial in origin.

Alluvial deposits and some Aeolian deposits of Quaternary age are also present in the study area. The rocks of Delhi super group are exposed in small discontinuous hillocks. Major part of the area, east of the

Yamuna is formed of Older Alluvium and fluvial Aeolian deposits. Older alluvium largely consist of polycyclic sequence of sand, silt and clay with kankar.

Geologically, the rocks of Delhi Super-group comprises quartzites within intercalations of schists-phyllites, belonging to Delhi super-group (Proterozoic) the whole assemblages in intruded by younger pegmatite and quartz veins (Haron 1953). The rocks in the central part extend as NE-SW trending ridge (known as the Delhi Ridge and Delhi-Sahibabad Ridge) upto Wazirabad in NE. The northern and central gently undulating plain comprises alluvial and fluvio-alluvial material at places with small aeolian rounds of Quaternary to sub-recent age.

The foregoing discussion substantiates the neglect of basic geomorphic factors in planning urban development and consequent irreversible urbanization problems. Proper geotectonic evaluation is vital, and needs to be done while planning further expansion to ensure sustainable development. This shall also help in identifying sites for open space and sequential land-use management covering canalization, laying roads, bridges, barrages, drains etc.

CHAPTER-IV

HYDROGEOLOGY

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Hydrogeology is concerned primarily with the mode of occurrence, distribution, movement and chemistry of water occurring in sub-surface in relation to the geological environment. It forms the basis of all planning for development and utilization of water resources. Management and development of groundwater has become basically a social issue in global perspective as every fact of human society has a growing demand for water. The scenario of groundwater hydrogeology, therefore, would increasingly embrace prognostic approach on the quantity aspects within the framework of various inherent variables present in the heterogeneity of the interactive dynamic processes. As progressive improvements and refinements in hydrological techniques result in more reliable forecasts of runoff, recharge, floods and droughts, it becomes possible to make better plans and choices for development of water resources (Todd, 1971).

Hydrogeology is an emerging science. It has started finding its own niche in the geophysical arena. Until recent past it was more of an appendage of hydraulic engineering and its scope was confined to rather limited set of systems and paradigms, and its tools and techniques were mostly empirical (Singh, 1982). However, with growing environmental awareness on one hand and digital revolution on the other in appreciation for the role of hydrology in addressing critical environmental problems began to develop (Hipel et al., 1994).

During a span of nearly four decades, hydrogeology has merged into a legitimate branch of geophysical science for the evaluation, analysis and management of groundwater. Nowadays there is increasing emphasis on applying the laws of science to solving hydrologic problems and verifying hydrologic theories using field or laboratory data.

Groundwater has now become the main sources of water supply because of increasing pollution of surface water. Groundwater in its natural state is invariably moving and movement of groundwater is influenced by the sequence, lithology, thickness and structure of the rock formation. The formation laws governing the movement of groundwater are the continuity equation and the Darcy flux law. When these coupled, the resulting equation is the governing equation for groundwater motion which is a parabolic partial differential equation (Freeze & Cherry, 1979). Depending upon the type of aquifer and assumptions made to simplify the geometric representation and the flow therein, the governing equation specializes into the Theis equation, poison equation, Boussinesq equation.

India is a vast country with a highly diversified hydrogeologic set-up. The ground water behaviour in the Indian sub-continent is highly complicated due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions. Studies carried out over the years have revealed that aquifer groups in alluvial/soft rocks often transcend the surface basin boundaries. Broadly two group of water bearing rock formations have been identified depending on characteristically different hydraulics properties, viz. Porous formations which can be further classified into unconsolidated and semi consolidated formations having primary porosity and Fissured formations or Consolidated formations which have mostly secondary derived porosity (Fig-4.1).

4.1 Ground Water Resources Estimation

Rainfall is the major source of ground water recharge in India, which is supplemented by other sources such as recharge from canals, irrigated fields and surface water bodies. A major part of the development of groundwater resources takes place from the upper unconfined aquifers, which is also the active recharge zone and holds the dynamic ground water resource. The dynamic ground water resource in the active recharge zone in the country has been assessed by Central Ground Water Board in association with the concerned State Government authorities and the National Bank for Agricultural and Rural Development (NABARD). The assessment was carried out with Block/Mandal/Taluka/Watershed as the assessment unit and as per norms recommended by the Ground Water

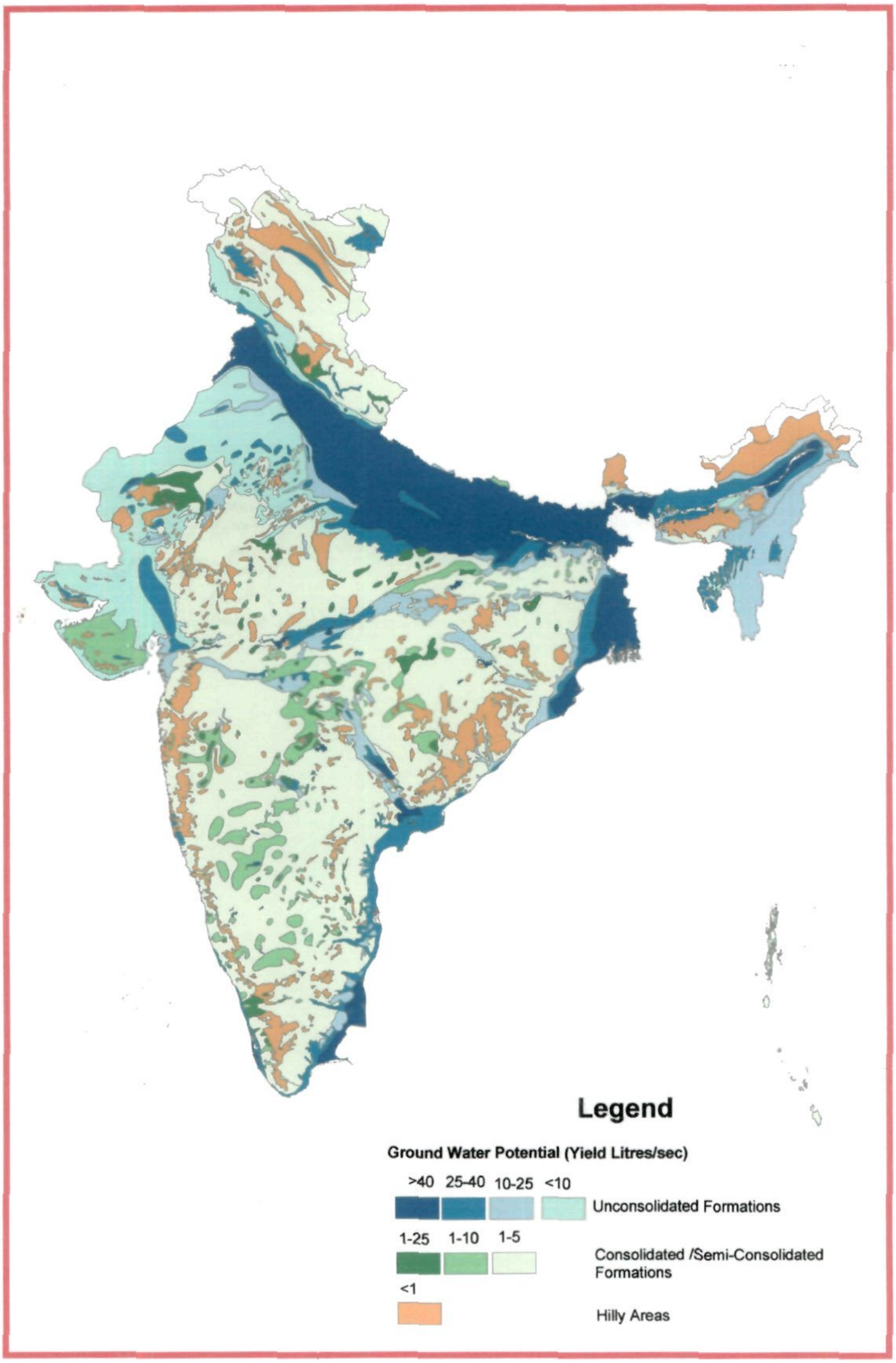

Fig.4.1. Hydrogeological map of India.

Estimation Committee (GEC)-1997. As per the latest estimates of 2006, the annual replenishable ground water resource in this zone has been estimated as 433 Billion Cubic Meters (BCM), out of which 399 BCM is considered to be available for development for various uses. The remainder of 34 BCM is set aside for natural discharge during non-monsoon period for maintaining flows in springs, rivers and streams. The ground water resources availability and utilization in India is pictorially presented in Figure 4.2.

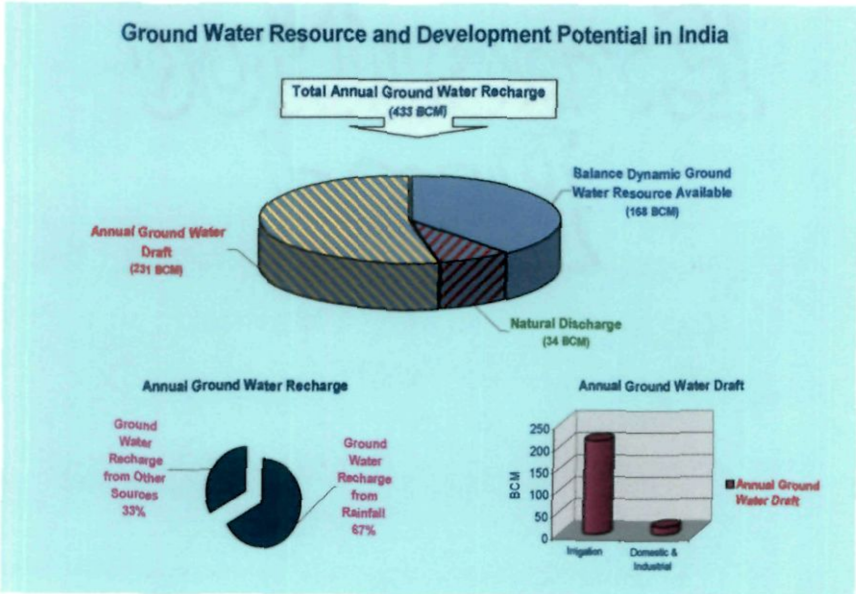

Fig.4.2:Ground water Resources Availability & Utilization in India

4.2 GROUND WATER DEVELOPMENT STATUS

4.2.1 Growth of Ground Water Abstraction Structures

Ground water extraction for various uses and evapotranspiration from shallow water table areas constitute the major components of ground water draft. In general, the irrigation sector remains the main consumer of ground water. Data available from the census of minor irrigation structures (Table.4.1) indicates a three-fold increase in the number of ground water abstraction structures from about 6 million during 1982-83 to about 18.5 million during 2001-02 (Fig.4.3).

Table 4.1: Growth of Ground Water Abstraction Structures in India.

Type of Structure	Number of Structures			
	1982-1983	**1986-1987**	**1993-1994**	**2000-2001**
Dug well	5384627	6707289	7354905	9617381
Shallow Tube well	459853	1945292	3944724	8355692
Deep Tube well	31429	98684	227070	530194

It is also seen that the growth has been more pronounced in shallow and deep tube wells (17 to 18 times) when compared to dug wells (about 2 times). This shift is probably the combined result of deepening ground water levels and advances in drilling and pumping technology.

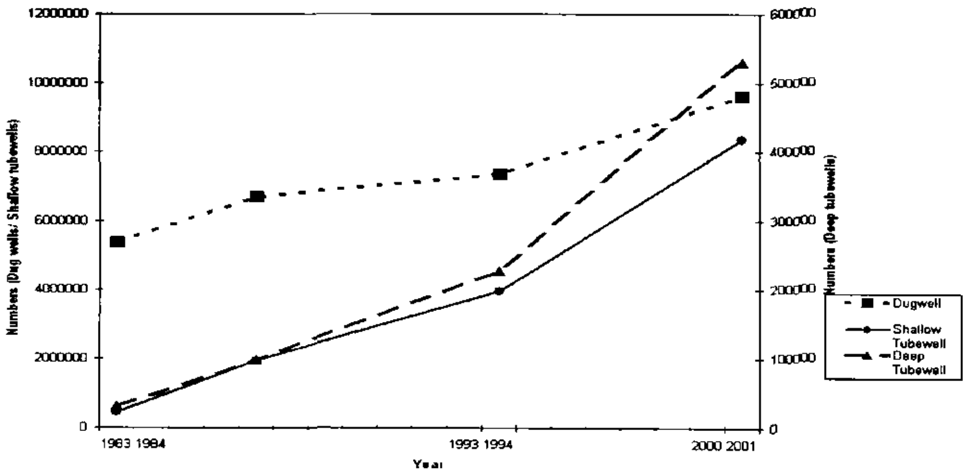

Fig. 4.3. Growth of groundwater structures over the years.

The ground water draft for the country as a whole has been estimated as 231 BCM, about 92 percent of which is utilized for irrigation and the remaining 8 percent for domestic uses. Hence, the stage of ground water development, computed as the ratio of annual ground water draft to net annual ground water availability, works out as about 58 percent for the country as a whole. However, the development of ground water in the country is highly uneven and shows considerable variations from place to place.

4.2.2 Categorization of Assessment Units

As part of the resource estimation as per GEC -1997 norms, the assessment units have been categorized based on the stage of ground water development and long term declining trend of ground water levels. As per the assessment, out of the total of 5,723 assessment units in the country, ground water development was found to exceed more than 100% of the natural replenishment in 839 units, which have been categorized as 'Over-exploited'. Ground water development was found to be to the extent of 90 to 100 percent of the utilizable resources in 226 assessment units, which have been categorized as 'Critical'. The categorization of assessment units for the country is shown in Fig.4.4.

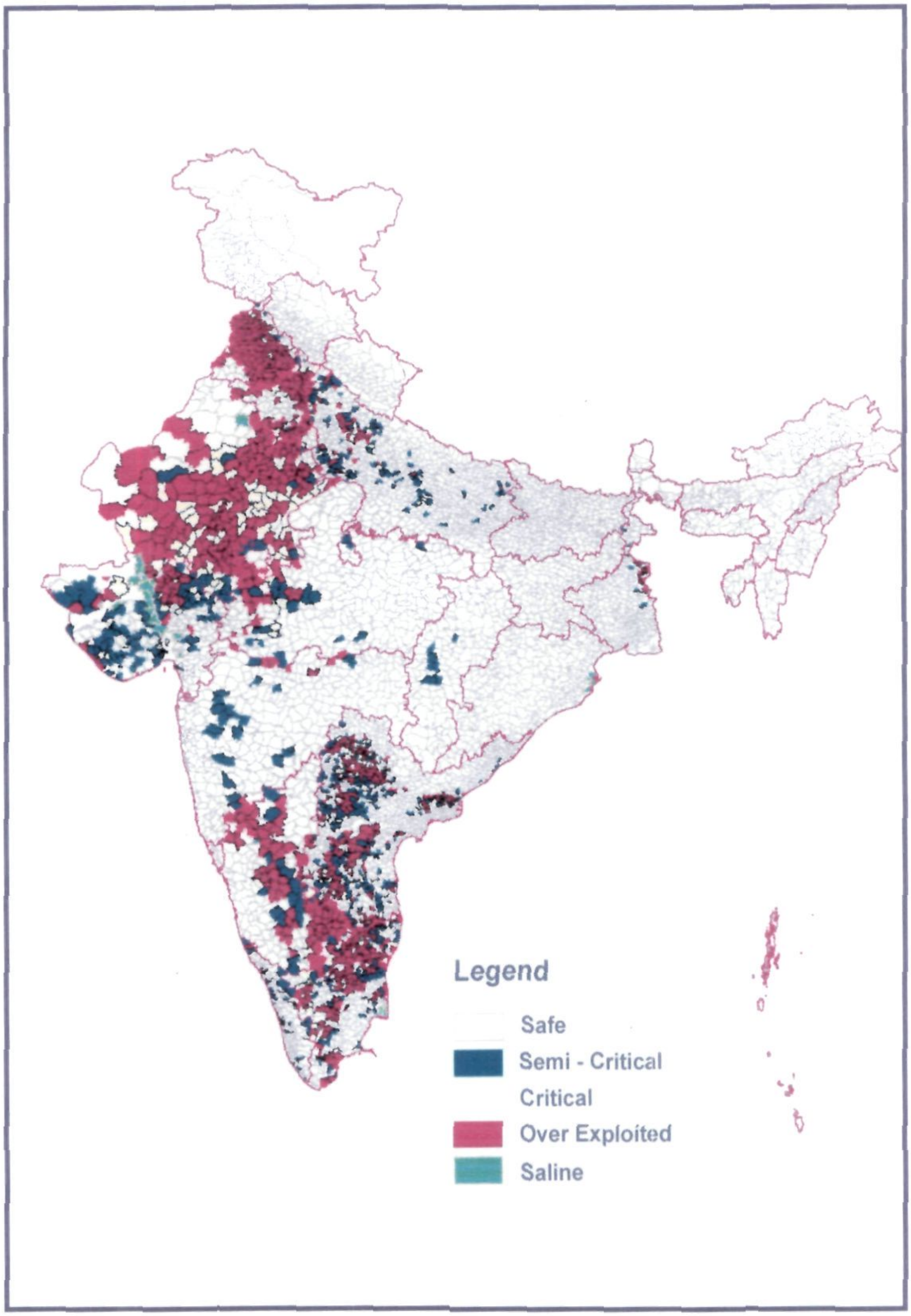

Fig.4.4. Categorization of Assessment Units Based on the Stage of Ground Water Development in India .

4.3 GROUNDWATER UTILIZATION

Groundwater development and utilization have increased immensely worldwide for irrigation, domestic and industrial purposes. The utilization of groundwater resources is therefore, of fundamental importance for the economic development of the area. With limited water resources ever-increasing population and simultaneous technological developments, the need for conservation, preservation and efficient utilization of available waters are nowadays being realized by all the concerned. Due to mismanagement of irrigated agriculture and certain misconceptions among farmers, many fertile lands have become water logged. Thus an efficient and scientific management of the irrigation water should become an essential part for all the planning and develop-ment works connected with water resources, to increase agricultural production necessary to meet food and water requirements of the fast growing population.

For a large proportion of the population of a region, water supplies depend on drawing groundwater from a large number of wells and tubewells. Since the available groundwater resources alone of a region do not suffice to satisfy the rapidly rising water requirements, long term hydrological planning envisages the extraction of large quantities of surface water.

India is gifted by nature with a large number of major rivers. There is an extreme disparity in distribution of water resources, spatially and temporally in these river basins due to unequal precipitation. The total utilizable groundwater potential of the country has been estimated as 43.2 m ha m per year. After making provision for domestic industrial and other higher priority uses the potential available for irrigation is 36 m ha m per year. Taking the country as a whole, about 1/3rd of the potential is estimated to be utilized at present. The percentage of ground water development in Uttar Pradesh is 37.67%. Groundwater is the major source of water supplies for domestic, industrial and agricultural purposes in the study area. The surface water is contributed by Yamuna and Hindon river.

The utilization of water both surface and sub-surface depends upon the groundwater resources of the area. With the establishment of industries and· rapid increase in population, there is profound increase in the demand of water supply.

4.4 HYDROGEOLOGICAL SETTING

The Ganga basin forms one of the most potential groundwater provinces of India (Pathak, 1978) of which the state of Uttar Pradesh forms an important part. Out of a total area of 234,423 sq. kms. of the state, an area of 2,00,492 sq. km. has been covered by systematic hydrogeological surveys. The greater part of the state is covered unconsolidated formations having extensive and productive aquifers with yield prospects of more than 15 m^3/hour. Extensive aquifers having yield prospects of less than 150 m^3/hour are located in Western Ganga-Yamuna 'Doab' covering the districts of Ghaziabad and parts of *Agra, Etah, Mainpuri, Mathura, Meerut, Muzaffar Nagar and Saharanpur* districts; in the central part of the state covering parts of *Barabanki, Faizabad, Lucknow, Rai Bareli, Sultanpur* and *Unnao* districts and in eastern part covering the district of *Ballia* and parts of *Azamgarh* and *Ghazipur* districts. Local and discontinuous aquifers capable of yielding more than 150 m^3/hour are encountered in intermontane Doon valley. Southern marginal areas covering most of the trans-Yamuna plains and the area covered by semi-consolidated formations in northern Uttar Pradesh have local and discontinuous aquifers having yield prospects of less than 150 m^3/hour. In southern Uttar Pradesh fissured sedimentary and metasedimentary formations form aquifers capable of yielding more than 20 m^3/hour while the crystallines have local and discontinuous aquifers having yield prospects of less than 20 m^3/hour.

The Yamuna river sub-basin comprises the western part of Ganga basin which forms one of the most potential groundwater provinces of India. The alluvial plain of Ganga basin, occupies a structural trough or down warp of earth crust, the origin of which is related to plate tectonic and Himalayan uplift. The Ganga plain is made up of a thick pile of quaternary unconsolidated sediments comprising clay, silt, sand and kankar in varying proportions, and are known to contain good aquifers. The entire basin has been covered by systematic hydrogeological survey (Sharma and Sharma, 1973, Sinha 1980, Pathak 1982, Bajpai, 1983, Kakar, 1989, Chaturvedi et al. 1992 and Khanna, 1992).

The Ganga plain in Uttar Pradesh has been divided into four hydrogeologic units, viz, Bhabar, Terai, Central Ganga plain and Marginal Alluvial plain. The heavily sediment loaded on their emergence from the hills dump their load on a relatively flat area of northern fringe in Ganga plain resulting in the formation of alluvial fans at the foot hills. The continuation of this process and consequent coalescence formed the Bhabar zone. Groundwater in this deposits occurs under unconfined condition and water level is generally deep being more than 30 metres below land surface.

The deposits of Terai zone are distal sediments of the Bhabar fans which were washed down and sorted into distinct grain size associations. This zone comprises predominant clayey sediments with intercalated beds of sand and gravel, and is characterized by moist, swampy, gently undulating, south perennial drainages, which emanate from the springs and amalgamate down stream to form important rivers. The top aquifers in this zone are generally unconfined and the water level is normally within 4 m below land surface. There are localized occurrence of flowing condition with piezometric head varies between 6.6 and 8.9 m above the ground level.

The vast alluvial tract lying south of Terai and bounded in south by Yamuna forms the hydrogeological unit of the Central Ganga plain and is considered to be the most important groundwater resources potential of Uttar Pradesh. This belt is a plain of low relief and numerous fluvial depositional and erosional features. Depth to water level generally varies from 2 to 12 m below the land surface. Because of rapid change in their thickness and texture of granular zones, there is wide variation in permeability and transmissibility of the aquifers.

Marginal Alluvial plain is characterized by restricted thickness of alluvium over the basement. It occupies the area south of Yamuna in western Uttar Pradesh and south of Ganga river in eastern Uttar Pradesh and Bihar. The water level generally ranges from 2.5 m to 28 m below ground surface. The discharge of tube wells varies between 60 and 240 m^3/hour for drawdown from 3 to 16m.

4.5 HYDROGEOLOGICAL FRAMEWORK OF THE STUDY AREA

The area under investigation occupying the Yamuna-Ganga basin and covers western part of Ghaziabad and north-eastern part of Noida.

The quaternary alluvium comprising sands of various grades, clay and silt intercalated with 'kankar' the various sand bodies forms the prolific aquifers. Groundwater occurs under semi-confined to unconfined conditions.

Kankar, silt and fine sand horizons, found within the uppermost clay sequence permit storage and movement of groundwater to a limited extent. This zone forms the water table aquifer and support hundreds of dug wells in the area.

Rainfall forms the principal source of groundwater recharge in the area, irrigation return flow, Yamuna and Hindon river, canals and numerous surface water bodies like ponds, lakes etc.

Groundwater plays vital role in determining transmitting and water bearing capacity of geological formations. The existing hydrogeological information, based on data available from Central Groundwater Board, was interpreted and analysed. To fill the information gap and to have a control on hydrologic system, entire study area has been covered through reconnaissance traverses.

In order to study the hydrogeological condition including groundwater movement and changes in water level in response to rainfall, evaporation, groundwater use and other local factors, systematic well investigations of 65 observation wells were carried out (Fig. 4.5). The pre and post monsoon water levels were measured in the observation wells during 2006 and 2007.

The collected water level data were used in the preparation of depth to water level maps, water level fluctuation maps and water table contour maps in order to demarcate the potential area for further groundwater development. The lithological logs of tubewells drilled by Geological Survey of India (GSI) were utilized for the preparation of fence diagram and cross sections to study the disposition of various aquifer systems and their vertical and lateral extensions in the area.

4.5.1 Sub-surface Geological Configuration and Aquifer Disposition

To understand the sub-surface configuration of aquifer system and nature of sediments, hydrogeological cross sections and a fence diagram have been prepared by utilizing lithological logs of the tubewells drilled by Central Groundwater Board of India (Fig.4.6).

Fence diagram technique is adopted for the study area to analyses the hydrogeomorphological condition in its vertical and lateral horizons simultaneously. The diagram is used to understand the sub surface geology of the area. It gives a three dimensional view of the litholoical variations. A reliable estimate can be made of the areal extent, depth and

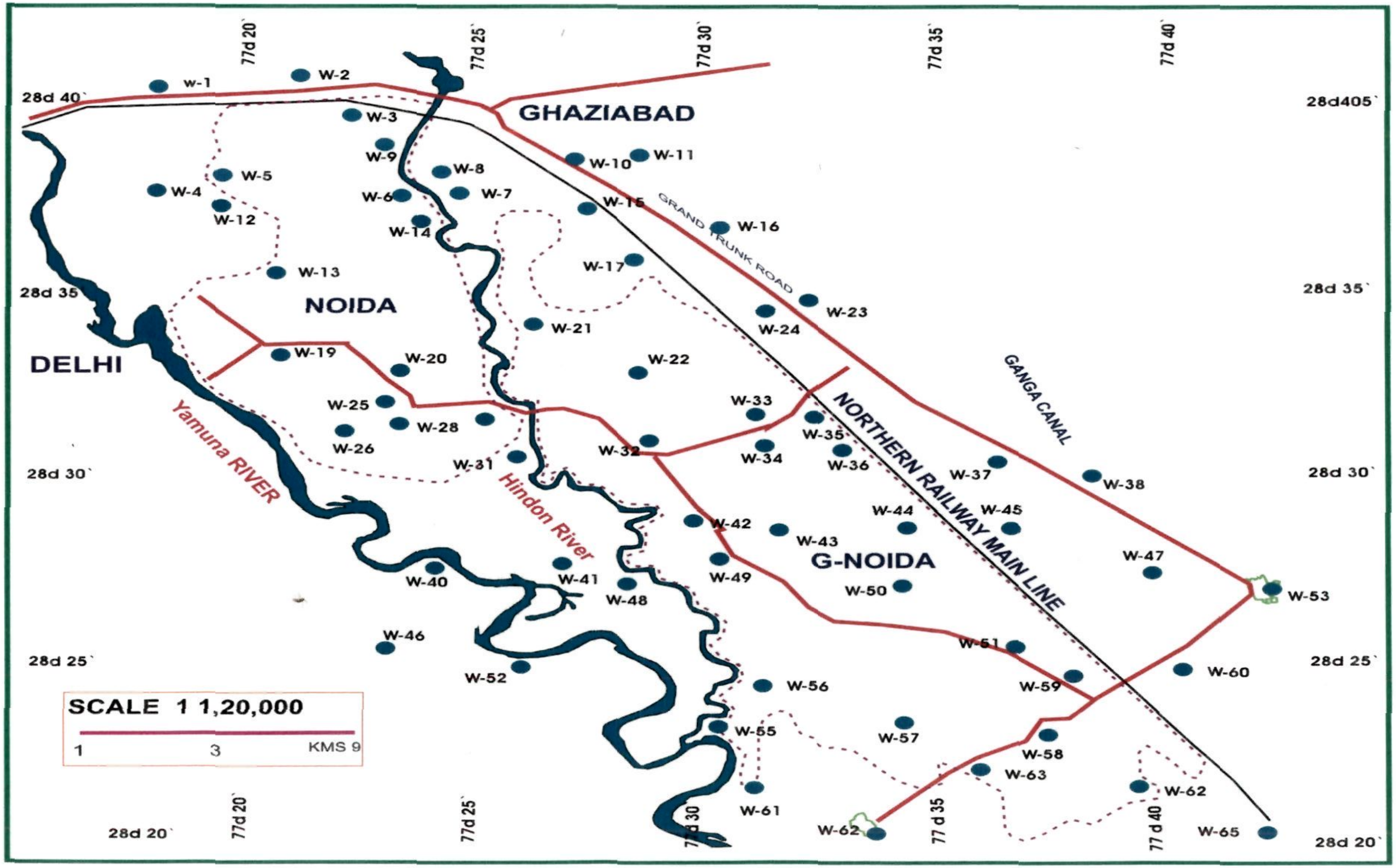

Fig. 4.5. Location map of observation wells.

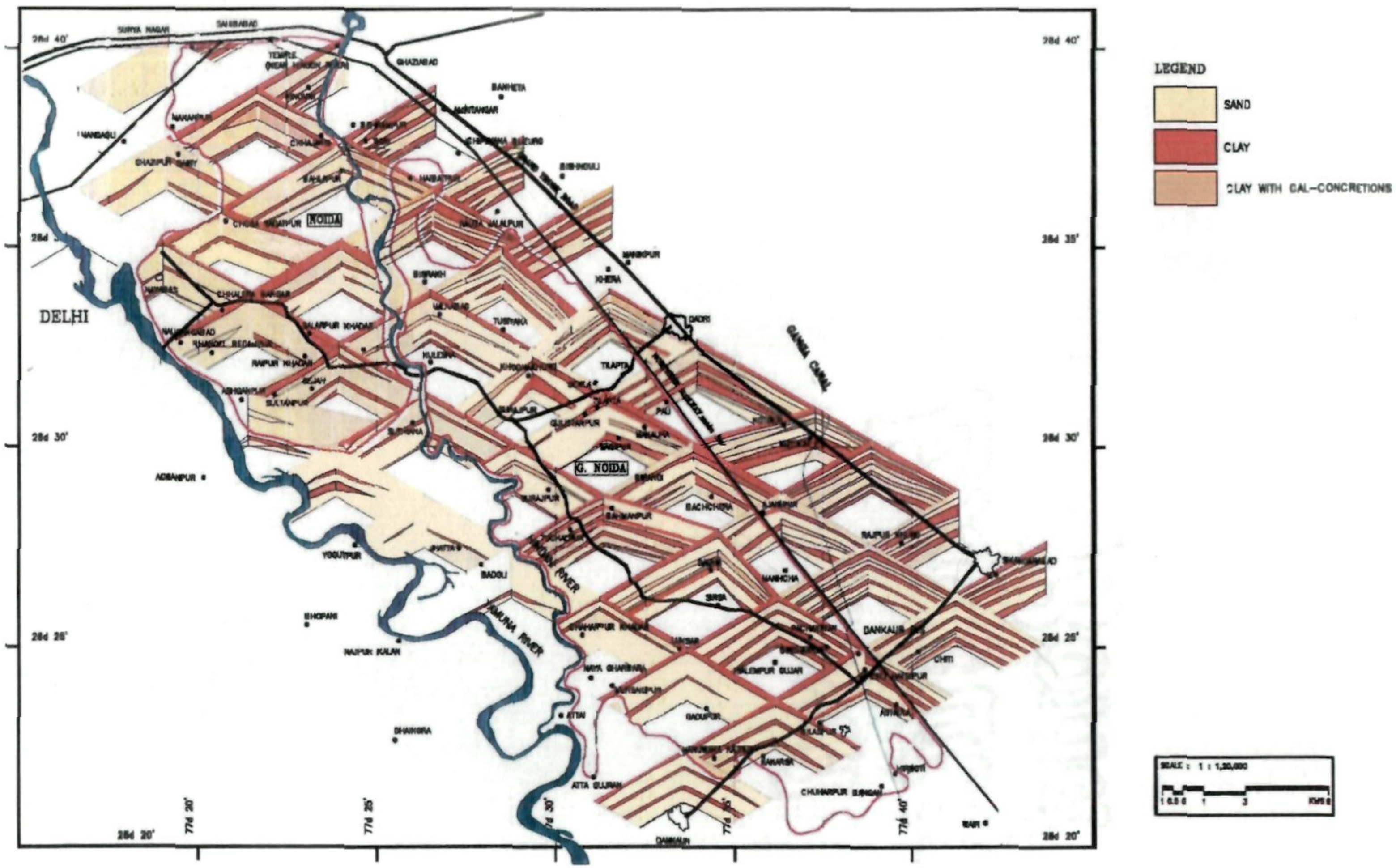

Fig. 4.6. Fence diagram showing sub-surface geological configuration.

type of aquifer. Fence diagram also provides an assessment physical characteristics and water yielding potential of the aquifer. This information can be used to correlate the utility of the aquifer to the water requirement for a specific design purpose.

Strata charts of five existing deep tubewells and data from terrametric soundings are used. Tubewells located at Kulesra (60 mts.), Surajpur (93mts), Khodna Khurd (72.5 mts), Sakipur (96 mts) and Tughalpur Haldona (350 mts).

Subsurface geology of the area has been described from the study of the lithologs, peizometers and strata charts from private, state tube-wells, deep pump wells and observation wells.

On observation of the fence diagram, it is clear that, there exists a multi-aquifer systems in the area. The top aquifer is unconfined in nature in general. Alternate clay and kankar beds indicate the deeper aquifers to be leaky confined in nature, fine to medium grained sand constitute the aquifer material in general. Layers of coarse sand are met occasionally in the area. Two or three layers of aquifer, ranging in total thickness 15 to 20 mts. have been observed at Kulesra, Surajpur, Khodnakhurd and Sakipur area.

4.6 OCCURRENCE OF GROUNDWATER

Occurrence of groundwater in the deposits depends on several factors such as size of the catchment, upstream of the cone, quantity of water discharged, shape of the cone structure, thickness, permeability and the nature of the basement rocks.

Alluvial deposits are highly porous and permeable because of the presence of sand and kankar. Groundwater occurs in the pore spaces of alluvial sediments in the zone of saturation. In alluvium, sand and silt-kankar form potential aquifer zones which generally occur within 40 metre to 50 metre depth. Groundwater occurs under phreatic condition at shallow depth, whereas at greater depth, it occurs under confined conditions. The thickness of alluvium comprising silt, sand, gravel and kankar in varying proportions increases from about 25 m in the area close to quartzite outcrops in the northwest to over 150 m in the south-eastern part of the area.

4.7 YIELD CHARACTERISTICS

Yield characteristics of an aquifer depends upon the porosity and permeability of the rock formation which depend on grain size, shape and distribution of pores, compaction of the stratum and drainage. Fine grained materials yield little water, whereas coarse grained materials permit a substantial release of water and hence serve as good aquifers. It is evident from lithologs data of tubewells drilled in the area that there exists an unconfined aquifer group comprising mainly sand and kankars within 40 to 50 m depth below which the sediments are predominantly clayey with thin sand/kankar aquifer zone.

Because of the presence of highly porous materials in the shallow aquifer zone as compared to deep aquifers zone, the shallow aquifer have better yield characteristics. There are large number of tubewells in the vicinity of Noida area, constructed for irrigation, drinking and domestic purposes. These tubewells tap water from water bearing zone within 70 m to 80 m depth and yield 375 litre per minute to 1500 litre/minute for 5 to 10 m of drawdowns.

In Ghaziabad, shallow aquifers down to 125 m depth yield 1500 to 2500 litre/minute, whereas deeper aquifers comprising mainly medium to fine with occasional coarse grained sand below 150 m yield 2500 to 3500 litre/minute. The average transmissivity of shallow and deeper aquifers is 150 m^2/day and 1700 m^2/day respectively.

4.8 DEPTH TO WATER LEVEL

One of the most important and common measurements in groundwater investigations is the determination of the depth to groundwater. In an unconfined aquifer, the water level in the upper surface of the zone of saturation where the pressure is atmospheric. Water level can be defined as the level at which water stands in wells penetrating the aquifer. However, the water level standing in dugwells are considered accurate enough to represent water level of an area. In existing dugwells in an area water level data are needed to define groundwater flow directions, regional variation in water levels over time and effects of pumping tests.

Water level data of 65 wells were used over a period of two years, with each years readings being taken twice, one in pre monsoon (June) and one in post monsoon (Nov.). The wells were fairly evenly spaced, at a distance of approximately 5 kms. The water level data thus collected were utilized to prepare the depth to water level maps of the study area.

On the basis of water level data collected from sixty five observation wells scattered in the study area, during June and November, 2006 (Appendix IV-A) and June and November 2007 (Appendix IV-B), depth to water level maps of pre-monsoon and post-monsoon periods (Figs.4.7,4.8,4.9 and 4.10) have been prepared.

Depth to water level (Pre-monsoon, 2006, 2007)

A perusal of the depth to water level maps of pre-monsoon, 2006 (Fig.4.7, Appendix IV-A) revels that the depth to water level in the area ranges between 2.92 m to 12.05 m below the ground level. Shallow depths to water level have been recorded near the Yamuna river at *Daktha, Surajpur, Rajpur Khadar, Makanpur* and *Chora Sadatpur*. Deep water levels occurred in pockets at *Sikandrabad, Bhopani and Kanarsa.*

Table 4.2: Numbers of wells in different ranges of water level depth Pre-monsoon (June 2006, 2007).

Years	**No of Wells**	**Depth to Water level range (m.b.g.l)**				
		Dry	**0-4**	**4-8**	**8-12**	**12-16**
2006	65	8 (12.30%)	7 (10.67%)	33 (50.76%)	16 (24.61%)	1 (1.53%)
2007	65	10 (15.38%)	10 (15.38%)	39 (60.00%)	5 (7.69%)	1 (1.53%)
Average%		**13.84**	**13.08**	**55.38**	**16.15**	**1.53**

Table 4.3: Numbers of wells in different ranges of water level depth Post-monsoon (June 2006, 2007).

Years	**No of Wells**	**Depth to Water level range (m.b.g.l)**				
		Dry	**0-4**	**4-8**	**8-12**	**12-16**
2006	65	Nil	14 (21.53%)	43 (66.15%)	7 (10.76%)	1 (1.53%)
2007	65	10 (153.38%)	12 (18.46%)	39 (60.00%)	4 (6.15%)	Nil
Average%		**7.69**	**19.99**	**63.07**	**8.455**	**0.76**

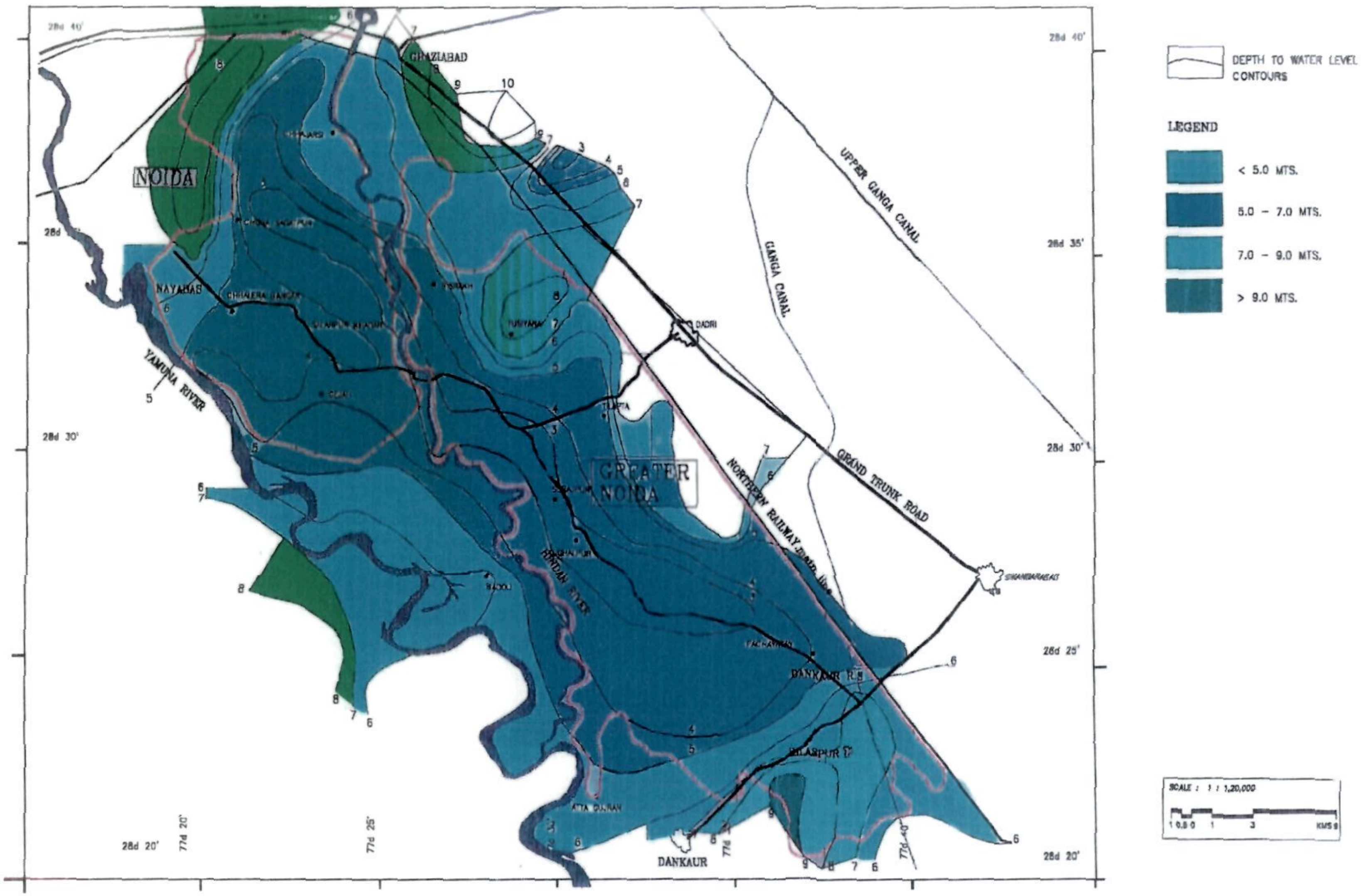

Fig.4.7. Depth to water level map, June 2006.

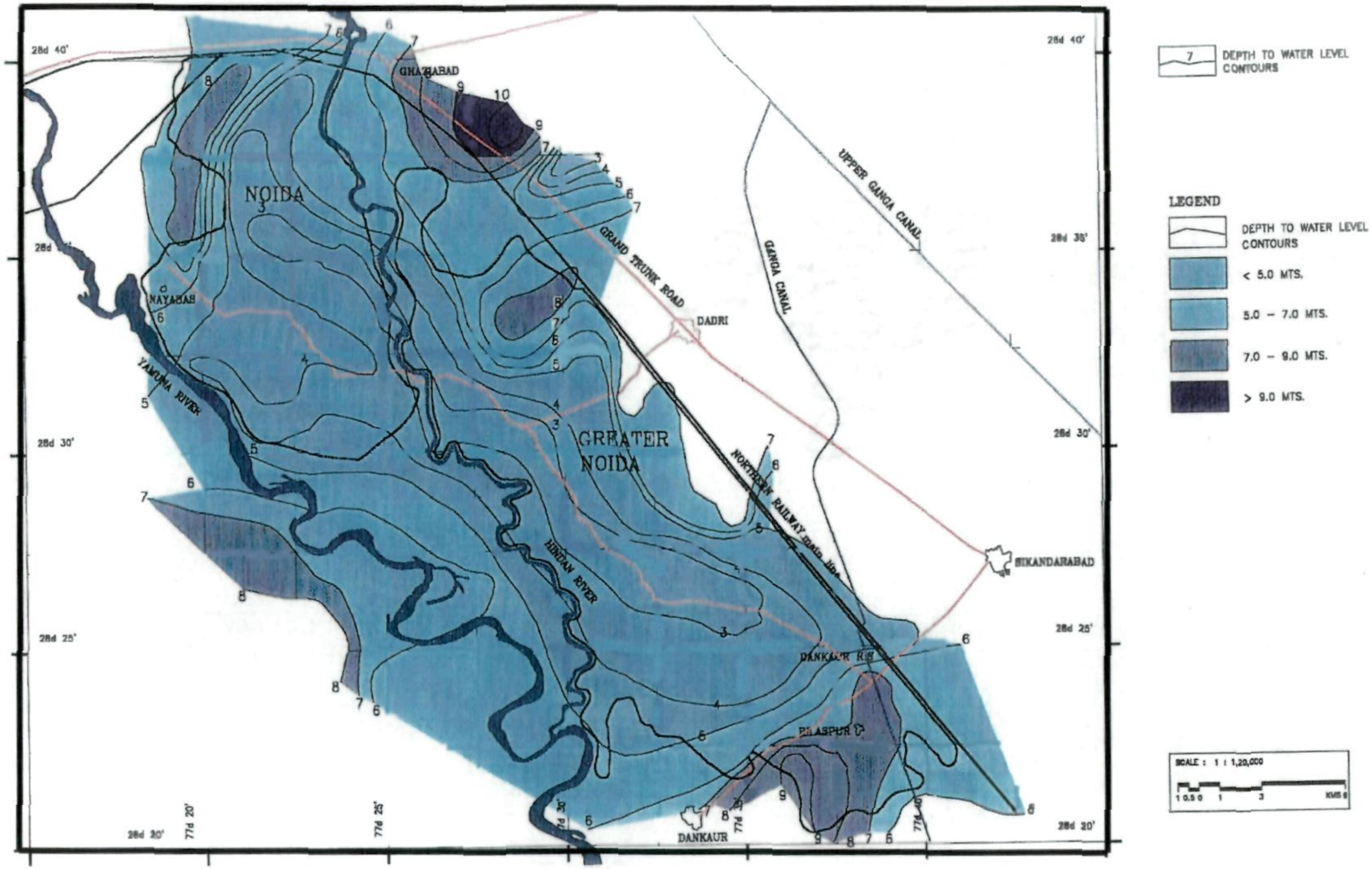

Fig.4.8. Depth to water level map, November 2006.

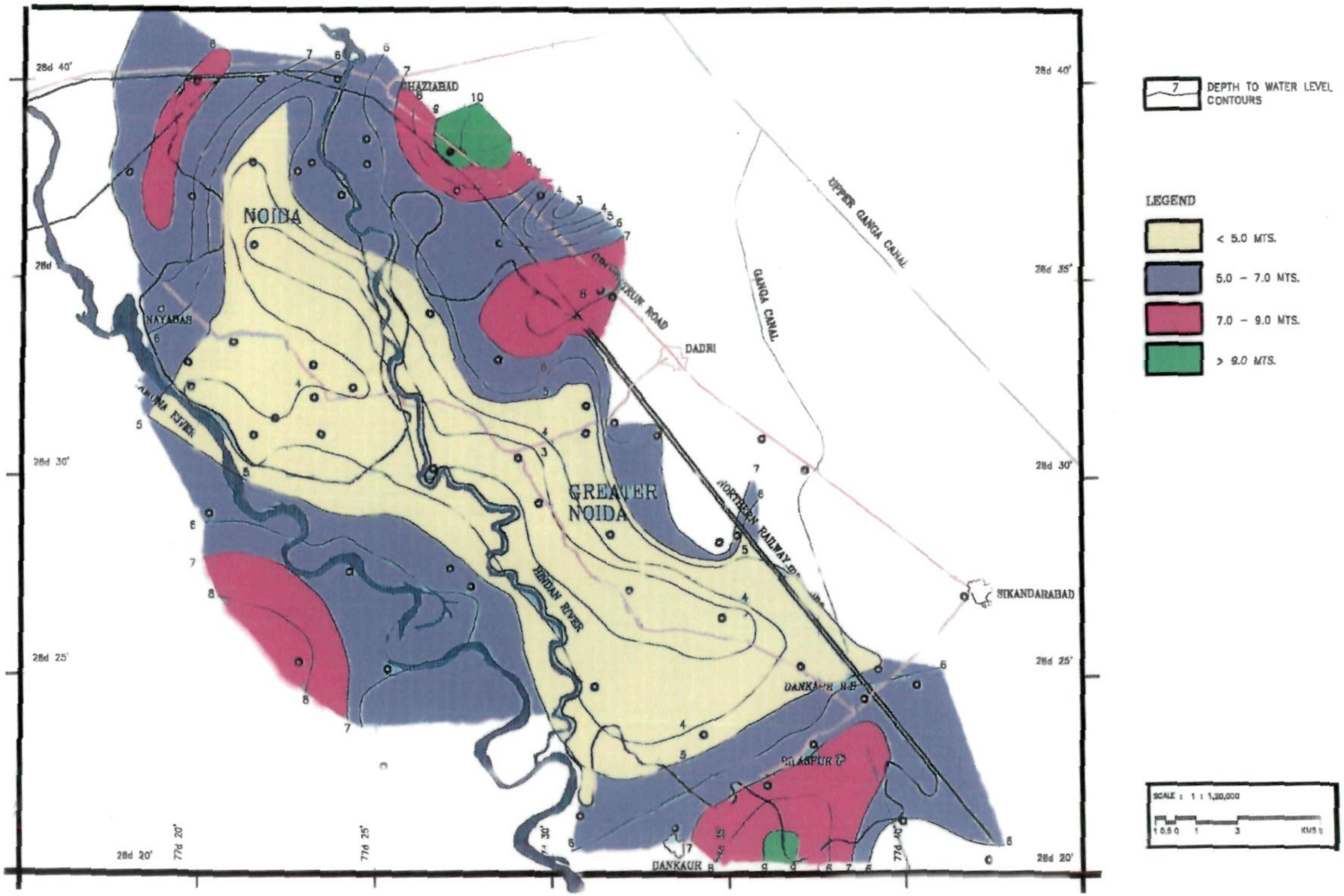

Fig. 4.9. Depth to water level map, June 2007.

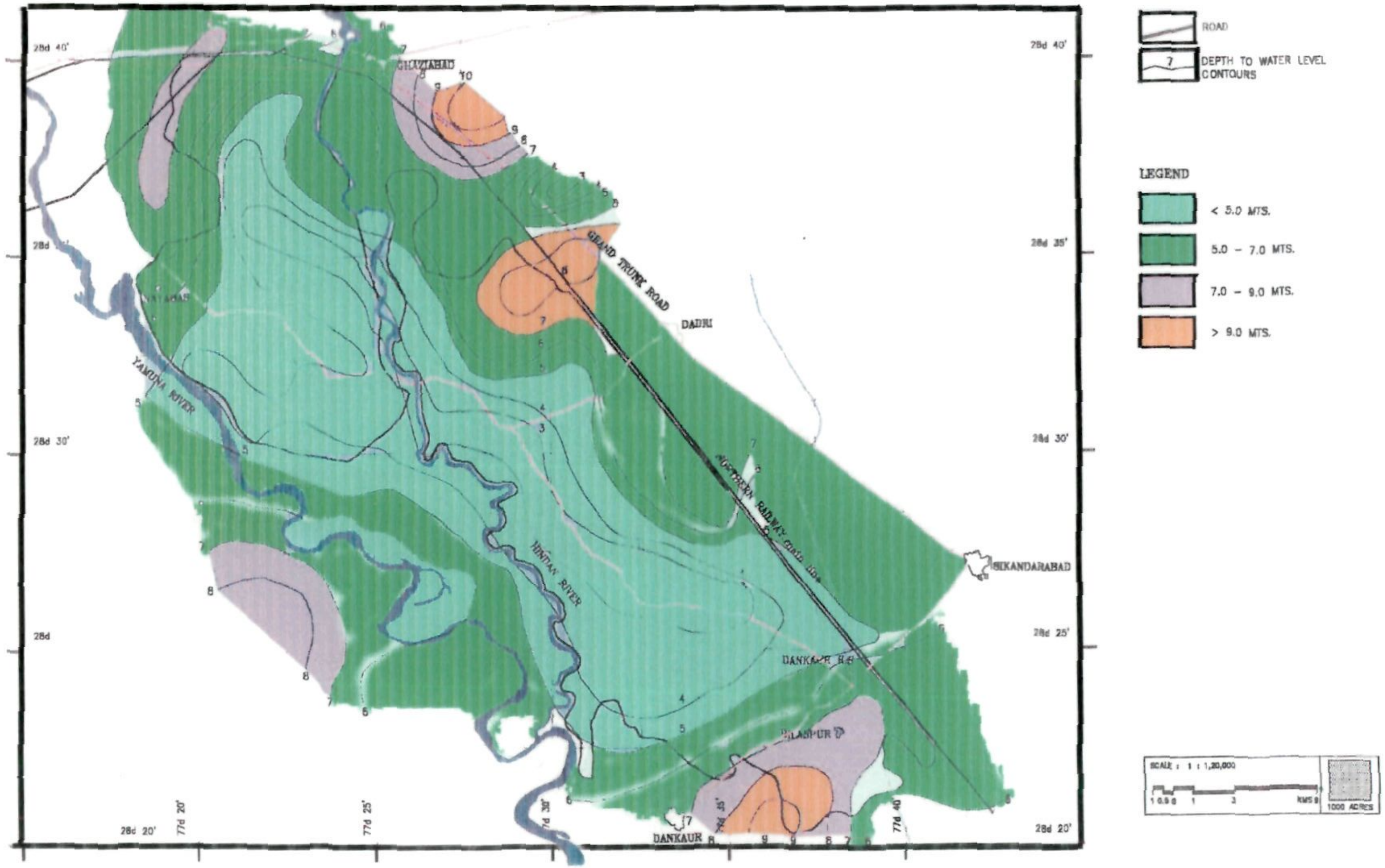

Fig. 4.10. Depth to water level map, November 2007.

During June, 2007 (pre-monsoon), the water level varied between 2.95 m to 12.32 m below ground level. The maximum depth to water level was observed at Sikandrabad and minimum at Surajpur. The deep water level occurring in patches may be attributed to excessive withdrawal for industrial, domestic and agricultural needs.

It is observed from Table 4.2, that during pre-monsoon period, 26.14% of wells shows depth to water level ranging between 8 m to 16 m below ground level, 50.76% of wells shows the water level depth between 4 and 8 m.b.g.l. and 10.76% wells are reported to have water level depth of 0 m to 4 m.b.g.l. in the year 2006. In pre-monsoon 2007, 9.22% of wells shows depth to water level ranging between 8 m to 16 m m.b.g.l., 60.00% are in between 4 m to 8 m.

Depth to Water Level (Post-monsoon, 2006, 2007):

Depth to water level during post-monsoon period varied from 2.20 to 12.00 m below ground level in 2006 and from 2.26 to 12.00 m.b.g.l. in 2007 (Appendix IV-A and IV-B). Figures 4.8 and 4.10 shows the depth to water level post-monsoon period during 2006 and 2007 respectively. The shallowest water level depth 2.20 m.b.g.l. during November 2006 and 2007 were recorded at Chora Sadatpur and the deepest 12 m.b.g.l. at Sikandrabad.

While comparing the water level depth of pre-monsoon and post-monsoon period (Table 4.2 and 4.3), it is seen that the average percentage of wells having water level depth to 0- 4 m.b.g.l. has increased from 13.08 to 19.09%. There is an average increase of 8.36% in the number of wells having water level depth in the range of 4 to 8 m.b.g.l. during post-monsoon period. Decreasing trends have been observed in the average percentage of wells having depth to water level more than 12 m.b.g.l.

4.9 WATER TABLE CONTOUR MAPS

The water table contour maps provide visual information on the slope of water table and the horizontal movement of groundwater in the direction of maximum gradient. The water table contour maps help to delineate areas of recharge and discharge, areal variation in the thickness and hydraulic conditions of aquifers and to interpret the nature of hydraulic boundaries and to quantify groundwater flow. The divergence of flow lines in water table contour maps indicates a recharge area whereas convergence of flow lines depicts a discharge area (Fig. 4.7,4.8,4.9 and 4.10).

The altitudes after level with reference to the mean sea level (m.s.l.) were determined from the water level data of observation wells collected during pre-monsoon and post-monsoon periods for two years (2006 and 2007) is surmised in Appendix IV-A and IV-B. To understand the groundwater regime and direction of groundwater flow in the shallow aquifer system, and to understand the inter-relationship between canal system and groundwater regime, water table contour maps with contour interval of two metres have been prepared.

Water within the ground moves downward through the unsaturated zone under the action of gravity, whereas in the saturated zone, it moves in a direction determined by the surrounding hydraulic situation.

Contour maps of groundwater levels, together with the flow lines, are useful data for locating new wells. Convex contours indicate regions of groundwater recharge, while concave contours are associated with groundwater discharge. Furthermore, areas of favorable hydraulic conductivity can be ascertained from the spacing of contours. In the study region these areas generally lie along the river Yamuna.

It is clear from the observation of the groundwater maps (Fig. 4.7, 4.8, 4.9 and 4.10) that contour spacing widens in areas predominated by sandy clay and the groundwater gradient increases towards the clay rich soil.

The movement of groundwater towards the decreasing head or potential is towards the river Yamuna. This behavior of groundwater imparts the effluent character to the river except in the area within Noida where river indicated influent behavior and contributing recharge to the groundwater in Noida.

4.10 WATER LEVEL FLUCTUATION

Water level in an area fluctuates in response to recharge and discharge from the aquifer system. Recharge takes place mainly due to precipitation as well as due to irrigation return flow. Excessive withdrawal of water from aquifer for domestic, industrial and irrigational needs and evapotranspiration is responsible for water level fluctuation. Fluctuations in water levels indicate both changes in the actual quantity of water stored in aquifers and movement of groundwater. The amount of water taken from or added to storage per unit change in water levels in unconfined aquifers is many times larger than in confined aquifer.

Based on water level depth data collected during pre and post-monsoon period for two years (2006 and 2007), water level maps indicating different fluctuation zones (Fig. 4.11 and 4.12, Appendix IV-A, and IV-B) have been prepared in order to depict the areas showing similar magnitude of water level fluctuation. It is observed that the quantum of seasonal fluctuation in the water level varies from place to place. In the present study seasonal fluctuation in water level varies from 0.17 to 1.7 m in 2006 and from 0.22 to 2.33 m in 2007.

Number of wells failing in different ranges of water level fluctuation and their percentage have been summarized in Table 4.4. It is evident from the table that in major parts of the area the water level fluctuation ranged between 0.6 to 0.8 m and more than 8 m. Only 10.54% of the wells are found to have water level fluctuation between 0.4 to 0.6 m in 2006 followed by 9.61% fluctuation in 2007. The variation in fluctuation in areas close to canal and river is probably due to the constant recharge of the aquifer through seepage resulting in the rise of water level.

Table 4.4: Numbers of wells in different ranges of water level fluctuation 2006-2007.

Years	**No of Wells**	**Depth to Water level range (m.b.g.l)**			
2006	57	**0-0.4**	**0.4-0.6**	**0.6-0.8**	**>0.8**
		14	6	7	29
2007	52	(24.56%)	(10.52%)	(12.28%)	(50.87%)
		5	11	8	28
		(9.61%)	(21.15%)	(15.38%)	(53.84%)

The little change in the fluctuation is attributed to the scanty and sporadic rainfall during 2006 monsoon or due to the predominance of low permeability horizon. The study further shows the upland area shows greater water level fluctuation then low land areas.

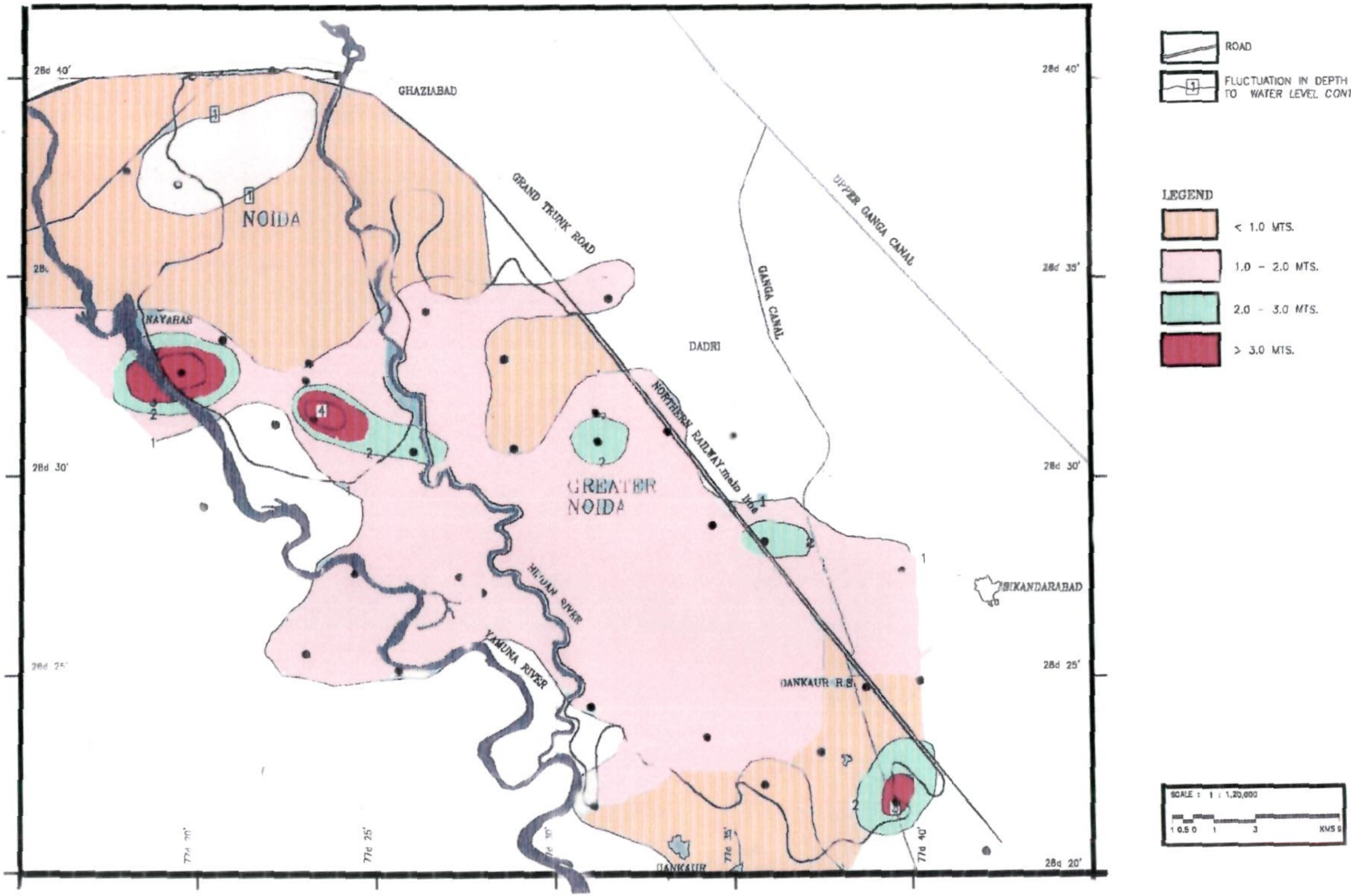

Fig.4.11. Water level fluctuation map of 2006.

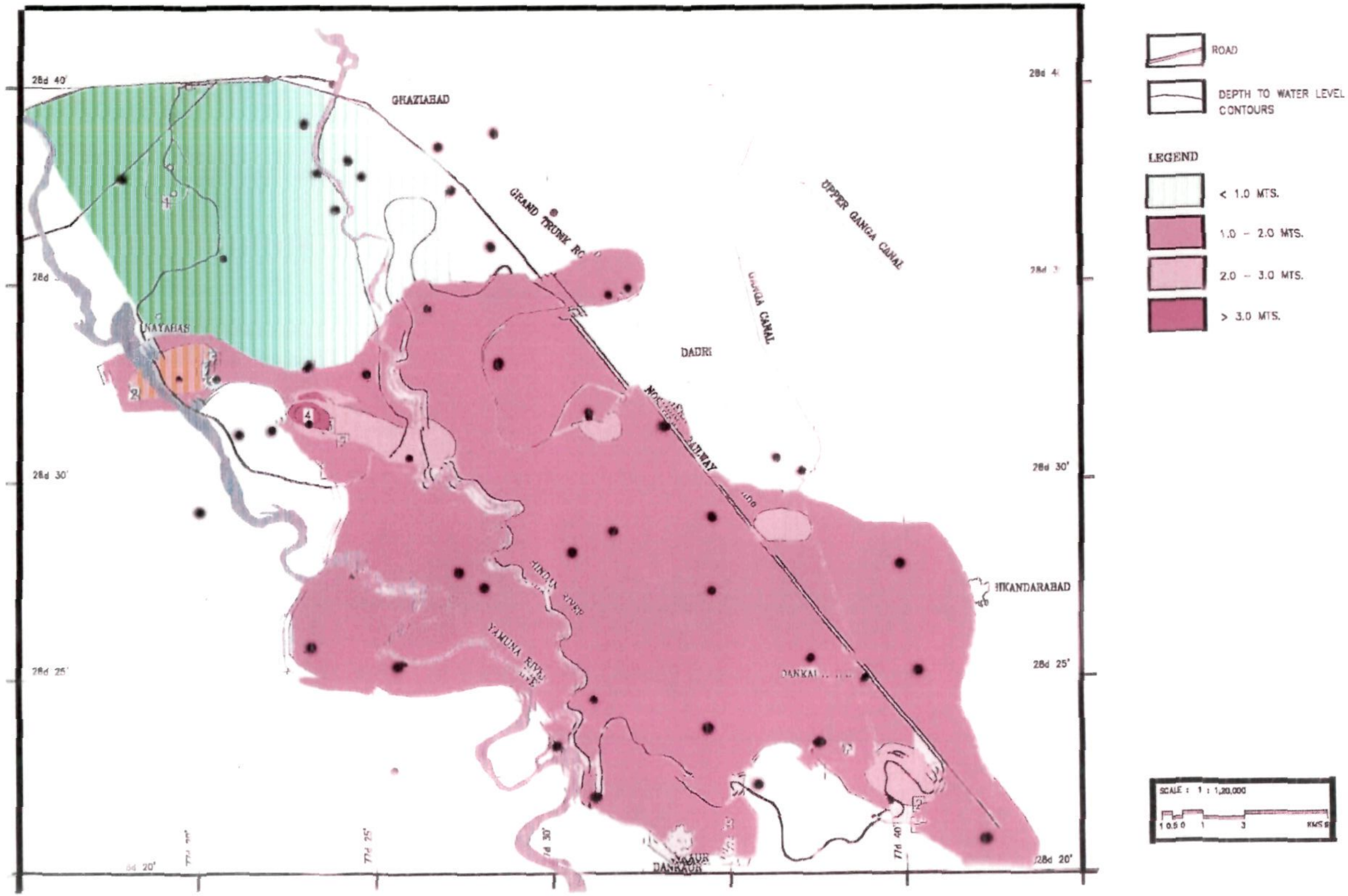

Fig. 4.12. Water level fluctuation map of 2007.

From the above discussion it would be apparent that the high fluctuation areas are also the areas of high relief with minor local variation at places. As revealed from the ground water movement that these upland tracks are the groundwater recharge areas from where the groundwater moves towards Yamuna and Hindon river or down to the regional gradient in its respective direction.

CHAPTER-V

IMPACT OF INDUSTRIES ON AQUATIC ENVIRONMENT

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Groundwater pollution may be defined as the artificially induced degradation of natural groundwater quality. The economic boom that India has experienced in the past twenty years has brought both increased industrial and urban waste disposal problems. Industrial treatment sludges, along with an array of other industrial hazardous and domestic wastes, were being indiscriminately dumped in the vicinity of factories, disused rock quarries and sand pits or in areas previously considered to be undesirable. Prior to 1980s, there had been little consideration given to the impact of wastes on land and water. But by the end of 1980s, the problem of managing sites had arisen from the contamination of soil groundwater and the potential risks to exposed population.

The groundwater pollution resulting from land disposal of liquid or solid waste has stopped the use of some sources of drinking water or precluded the future use of groundwater for drinking. When the wastes discharged on land are not concentrated or highly toxic, soil and strata may partially or completely purify as a result of attenuation reactions. However, this capacity is not ultimated and with overloading of pollutants, serious pollution of groundwater may occur.

Man has, from his earliest history been engaged in the process of taking materials from the earth. The water and air and then using them with increasing technological ingenuity to make new chemical agents, eventually with returning them in some form to the earth, water and air. This process provides a broad way of man made exposures to the numerous chemical environmental agents which might be contrasted with those of primitive man. The effect of man made exposures have some times been beneficial, even life saving as well as some times detrimental to health, is indisputable. The environmental toxicologists must attempt to quantity the conditions of exposure that produce unwanted effects as task which is monumental when one considers the vast number of chemical agents in the environment. The variable circumstances and duration of exposure and the complexity of health effect which may result from interactions of simultaneous exposures to multiple agents.

5.1 CAUSES OF WATER POLLUTION

The origin of pollutants can be traced to their natural occurrence on the earth, formation by transformation and concentration of natural substances and their manmade synthesis (Goel, 1997). The pollutants may arise quite naturally to form part of background concentrations in the environment. However their uniform distribution and genetic selection have ensured that they cause few troubles and are even absorbed by plants and animals without any significant effect. Many of them are excreted or detoxified by the organisms.

Some naturally occurring pollutants forming the background concentrations are oxides of nitrogen, heavy metals, hydrocarbons and radioactive substances. Some pollutants can be formed by the way of concentration and transformation of naturally occurring compounds during their domestic, agricultural or industrial use. Some important examples of pollutants originated in this way are the generation of sewage and the waste water containing agrochemicals, petrochemicals, certain pesticides and radionuclides, heavy metals and hydrocarbons.

Many chemicals do not occur in nature and pollution caused by them is entirely man-made. For example plastics, petrochemicals and synthesis of various pesticides have introduced a large number of chemicals in the environment that has created severe environmental problems. Several of these compounds like plastics and some pesticides are non-biodegradable facilitating continuous build-up of their concentrations in the environment.

Over the last decades considerable attention has been focused on environmental consideration. Infact, groundwater protection and restoration of contaminated soils and waters is an issue that has come under increased public scrutiny. In order to minimize the adverse effects of pollution and to take remedial measures, it is necessary to study the mechanism of groundwater pollution, the controls on release of pollutants and sub-surface movements.

5.2 INDUSTRY AND WATER POLLUTION

Various kinds of pollution are caused by inadequately treated industrial wastes. Organic wastes come mostly from food packing plants, petroleum refineries, petrochemical plants and pulp mills. Inorganic wastes are chemicals, such as acids and cyanides, that discharge from various industries. There is also pollution from insoluble particles (such as other wastes from mineral processing) that may make the water turbid or may settle to the bottom and smother purifying organisms. Finally, there is thermal pollution produced when heated water is discharged to a stream or lake where it raises the receiving water temperature above the natural level.

Industrialization of any country unavoidably creates environmental pollution problems. Water pollution normally manifests itself with poisoning of aquatic life resulting in the reduction of the quantity and quality of fish and others aquatic life. Complaints regarding water pollution are heard both from professionals and amateurs as well as from common men. Further, water supplies get endangered because of indiscriminate discharge of untreated industrial wastes into the Yamuna river.

In India the role of industry in preventing and controlling water pollution has been unfortunately rather negative, since the industry considered investment in waste water treatment as non-remunerative; it is a burden on the industry. With the ever increasing complaints of growing water pollution and ever growing demand for good quality water by industry itself, pollution control acts have been enacted by several countries including India. This has forced the industries to look into the whole problem of pollution control and not merely treatment and disposal of waste waters. Such an approach has helped many countries in preventing pollution by reuse of water in their production process and in reducing the cost of treatment by recovery of bye-products from process waste-waters.

The area under study lies in the upper Yamuna-Hindon doab comprising the districts of Noida and Ghaziabad. These districts have been selected to find out the extent and causes of water pollution, because there are the areas in this region, where the industries have developed rapidly and are likely to grow more in this decade.

In the study area the various industries could be grouped as follows:

1. Manufacture of food product industries,
2. Manufacture of beverages, tobacco and tobacco products,

3. Manufacture of cotton textiles,
4. Manufacture of wool, silk and synthetic fibre textile,
5. Manufacture of paper and pulp products and printing and publishing industries,
6. Manufacture of rubber, plastic, petroleum and coal products,
7. Manufacture of chemicals and chemical-products (except products of petroleum and coal), and
8. Manufacture of metallic and non-metallic mineral products.

These industries are located at the fringes of Yamuna river basin, mainly in Noida and Ghaziabad and discharge their wastes in the Yamuna and Hindon river through big and small drains, that are connected to the main factories of the city. The pollution load of Ghaziabad town is shown in (Fig 5.1). An industrial survey has been conducted to find out the extent of pollution by some industries which are generally located in the Yamuna river basin and discharge their poisonous wastes into Yamuna-Hindon sub-basin (Table.5.1).

5.3 GROUNDWATER POLLUTION IN THE HINDON RIVER BASIN

The Hindon River, historically known as the *Harnandi* River, is a major source of water to the highly populated and predominantly rural population of Western Uttar Pradesh province. The Hindon River originates in the lower Himalayas at *Pur ka Tanka* village situated in the upper east area of Saharanpur district. The river flows for 260 kms through six districts (Saharanpur, Muzaffarnagar, Meerut, Baghpat, Ghaziabad and Gautambudh Nagar) until it's confluence with the Yamuna River towards south of Tilwara village in Gautambudh Nagar district, downstream of Delhi. The headwaters are ephemeral, with a seasonal monsoon fed flow between July and March only. Low flows in the headwaters is exacerbated by over abstraction of surface and groundwater. The Hindon River has two main tributaries, the Krishni River which originates at Kairi Village and joins the Hindon at *Barnawa* Village, and the *Kali River* (West) which originates at *Dhanakpur* Village and joins the Hindon River at Pithlokar. The Hindon River drains a catchment of approximately 5,000 km^2 of largely agricultural land while flowing through a number of substantial sized towns and villages.

Water is perhaps the most valuable intake necessary for our survival. It is estimated that 70% of all the available water in India is polluted (Ghosh, 1992). Noida and Ghaziabad adjoining National Capital Territory of Delhi are the most industrialized districts of Uttar Pradesh, India. There are more than three thousand small and large scale industries manufacturing electrical goods, engineering equipments, tractors, transport and agricultural implements, rubber, tyres, paper, plastics.

textile and chemical industries etc. Extensive industrial expansion, urbanization and population explosion have changed the environment and natural ecosystem of the area. Groundwater pollution does play an important role in the assessment of the environmental quality of many areas (Bouzza et al., 1998). It is fully recognized that, although the process in the soil occurs slowly and often without immediate and dramatic consequences, the long term effects of contamination will be serious and possibly irreversible.

Groundwater in its percolation through soil and rocks leaches out soluble salts and is thus typically mineralized and some time heavily so the vulnerability of groundwater contamination is determined by the hydrological setting of the aquifer, the nature of the contaminants and the effectiveness regulatory actions. In the study area, groundwater pollution has been noticed, especially in the shallow water aquifers due to percolation of sewage, industrial liquid wastes and landfills contaminations in Ghazipur area.

The Hindon River is utilized by a wide range of industrial uses along it's length. Indeed, these industries both abstract large volumes of water from the river for their manufacturing processes, and also discharge their industrial effluents, often with nominal or no treatment, directly to the river. The rich aquatic ecology that is expected to be abundant within this rural state, is now absent. This study was therefore implemented as a result of an increasing awareness of the toxic contamination of the Hindon River, and the compromised human health identified within the population of the river catchment. This heavy loading of industrial effluent discharge directly into the Hindon River places an intolerable burden on the river's natural ability to assimilate pollutants. Key contaminants identified within the effluents of these industries include a very high loading of organic pollutants and suspended particulate matter (paper mills, sugar mills, distilleries, tanneries, slaughter houses and dairies), heavy metals (sugar and paper manufacture) and frequently pathogens as a result of contaminated raw materials entering the plants. This current study demonstrates the devastating effect that these toxic contaminants have on the health of the river ecosystem and the human population who are required to use the water. Dilution of effluent with freshwater is a commonly used and can be an effective treatment. However, this treatment requires good quality and adequate quantity of water within the receiving river. The Hindon River and tributaries receive such a high loading of effluent that dilution with freshwater is no longer a viable treatment. Freshwater flows within the river system are further reduced by diversion of water from the Hindon River through the Hindon

Cut Canal to the Yamuna River, and by the abstraction of high volumes of water for *sugar* and *paper manufacture*, and *crop irrigation.*

Agricultural practices within the Hindon River catchment have an important effect on the quality of the river. The river is a primary source of water for irrigation of agricultural land in the locality. Agriculture is the dominant economy of Western U.P. which is largely rural. The main crop grown is sugarcane, a crop that is well known for the large volumes of water required for a successful harvest. Substantial quantities of water are therefore abstracted from the Hindon River and underlying groundwater resources throughout the catchment, for crop irrigation. Abstraction for irrigation reduces natural freshwater flows within the Hindon River, reducing dilution potential of the river and concentrating the effects of other pollutants entering the river. Irrigation water also deposits on land, the contaminants carried in the water column which then leach through the soil profile to underlying groundwater aquifers.

Surface water run off from agriculture carries with it a number of suspended pollutants particularly elevated suspended sediments due to soil erosion, and agricultural chemicals such as pesticides and fertilizers. Agricultural chemical fertilizers have also been demonstrated to contain heavy metals.

Use of the river for disposal of untreated human sewage is a primary cause of poor water quality within the Hindon River. The river receives large volumes of untreated sewage and municipal wastes from all population centres within the catchment. The wastes of Ghaziabad city are discharged directly to the river through the big drain, followed lower in the catchment. The lower reaches of Hindon River catchments receives further heavy loading of municipal effluents of Ghaziabad through the three sewerage drains and the Indrapuram Sewage Treatment plant. However, this treatment plant does not have adequate volume capacity and is inadequate to efficiently treat all domestic and municipal wastes in the catchment. There are no other formalized domestic waste water drainage systems along the course of the river which receives raw domestic waste directly from all the villages and towns through which it passes via open channels. Untreated municipal wastes are known to contain a very high level of organic pollutants and suspended particulate matter, disease causing bacteria and other pathogens, as well as heavy metals which are not removed by conventional treatment. The river also receives a high loading of degradable and non-degradable domestic generated litter.

The Yamuna Action Plan aims to control untreated municipal drainage from a number of towns within the Hindon River catchment, including Ghaziabad and Noida. However, remediation of the heavy contamination of the Hindon river. pollution from agricultural run-off, including pesticides, or industrial contamination from effluent disposal. While attempts to increase sewage treatment provision within the catchment is necessary, such treatment does not remove industrial or pesticide contamination from drinking water. This highlights the need to control such discharges at source, as post-discharge treatment is not a viable option.

Fig. 5.2. Industrial effluent from the sugar mill drain, exhibiting high loading of organic pollutants at Gaziabad.

5.4 GROUNDWATER POLLUTION DUE TO HEAVY METALS

The industrial wastes have the greatest potential for polluting the receiving waters. The nature and composition of industrial wastes widely vary from industry to industry and even within the same industry depending upon the raw materials, processes and operational factors. The industrial wastes may have pollutants of almost all kinds ranging from simple nutrients organic matter to complex toxic substances. The wastes include solid as well liquid wastes. Liquid wastes can be generated by different industries, dredging and also by water produced through dewatering of pits. The industrial wastes may contain heavy metals such as lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn), Nickel (Ni) etc. The concentration of these heavy metals may range from 100 to 10, 000 ppm in industrial wastes such as those originated from pulp and paper and chemical industries.

In the study area, untreated or partially treated effluents of industries are often discharged in the premises of the industries in the depressions which find its way to groundwater system. Part of industrial effluents are directly discharged through unlined channels into Hindon river, small drains and Yamuna river. There are large number of dyes and pigments, food processing and steel industries in Noida and Ghaziabad. For manufacture of dyes, heavy metals and their salts, acid and alkalies are used (Ghosh, 1992). Most of these, besides small quantities of intermediate compounds along with final products are discharged into waste water which ultimately joins the groundwater. Food processing wastes from meat, dairy and sugar-beet processing, distilling and canning operation generate large amount of organic by-products that have been disposed off as waste water. When the waste water is discharged along with this by products into surface water, it leads to high BOD and consequent oxygen depletion in the receiving water.

The effluents released from metals industries, steel mills, machine tool factories are non-fermentable wastes and are generally characterised by low pH and high concentration of trace elements. The toxic effluents are discharged by electroplating units, dyeing and chemical industries, tanneries and factories manufacturing insecticides. The major effects of toxic discharges on aquatic fauna and water quality are fish death and contamination of water by heavy metals (Chowla et al, 1986), pesticides and detergents (Mishra, 1982).

The solid waste from the industrial belts of Noida and Ghaziabad is dumped in the vicinity of factories which is subjected to reactions with percolating rain water and finally joins the groundwater. During reaction this percolating rainwater picks up a large number of ions and trace elements and reaches the water level as leachate. It follows the flow of groundwater and spread over a large part of the area in groundwater system and hence pollutes the water. The inappropriate and often careless handling of industrial hazardous wastes create problems for human health and the environment. Effective control of the hazardous wastes is therefore, of paramount importance for proper health and environmental protection as well as natural resource management.

Various parameters that have potential for groundwater pollution and are associated with waste water discharged by major industries are given in Table 5.1.

5.5 GROUNDWATER POLLUTION DUE TO URBAN AND DOMESTIC WASTES

Domestic waste in the study area is organic in nature and gets oxidized by bacterial decomposition to nitrate, phosphate, carbondioxide and water. Urban and domestic waste of Noida in some localities where sewer pipes have been laid are passing through pipes in a Gaunchi drain which is lined for some distance and is unlined for the remaining portion. This drain passes through the rural areas and the waste water of the drain is being utilized for irrigation purpose. This may be one of the reason for groundwater pollution in Noida.

Domestic sewage consists of water borne waste of the community and contains about 99% of water and 1% solids. The major problem associated with sewage are the production of odours and spread of disease, organic pollution which leads to oxygen depletion in receiving water. The disposal of solid domestic wastes poses many problems depending upon both the type of waste and disposal method employed. Hundreds of tons of garbage and hazardous wastes are deposited in landfill in Noida and Ghaziabad. The leakage of leachate through the base of landfill to groundwater is one of the most studied parameters. Most sources of liquid that may eventually become leachate are water such as (i) precipitation falling directly onto the landfill, (ii) surface flow that has run into the landfill, (iii) groundwater inflow through a portion of the landfill lying below the groundwater table and (iv) the liquid fraction of the waste disposed in the landfill.

Leachate generation rate in arid climate may be very low. Kenan (1986) has indicated that in regions receiving less then 300mm of rainfall, landfill may never produce leachate. In a landfill biochemical decay of the organic material results in the evolution of gases and hazardous liquids which cause extensive pollution of groundwater. Well designed landfill is an important method of waste control. Representative ranges of various inorganic constituents in leachate from sanitary landfill is given in Table 5.3.

Septic tank, disposal pit and cesspools contribute- filtered sewage effluents directly to the ground are the more frequently reported sources of groundwater contamination especially in rural and sub-urban areas of Ghaziabad and Noida (Fig 5.3 & 5.4).

Table 5.1: List of industries discharging industrial waste in Hindon river.

Sl. No.	Name & Address of the Industry	Product	Effluent Discharge (KLD)
1.	M/s Chemolup Tissues (P) Ltd., Meerut Road, I.A., Ghaziabad.	Media Craft Paper 10 T/Day	800
2.	M/s I.T.C. Ltd., Meerut Road, Ghaziabad	Cigarette	50
3.	M/s Samtal Electron Devices Ltd., Meerut Road, Ghaziabad	Electron Guns 415000 Nos/month	80
4.	M/s Crop Health Products (P) Ltd., (Unit-1), Meerut Road, Ghaziabad.	Pesticides & Formulations	0.4
5.	M/s Indofos Industries Ltd., Meerut Road, Ghaziabad.	Control Panels	200
6.	M/s Sri Ram Piston & Rings Ltd., Meerut Road, Ghaziabad.	Piston & Rings	225
7.	M/s Mascots Tools India Ltd., Meerut Road, Ghaziabad.	Hand Tools 65 T/month	170
8.	M/s Dewan Reclaim Rubber, Meerut Road, Ghaziabad.	Reclaim Rubber Sheets	03
9.	M/s Hamdard (Wakf) Laboratories, Meerut Road, Ghaziabad.	Ayurvedic & Unani Medicines	300
10.	M/s Unichem Laboratories, Meerut Road, Ghaziabad.	Medicines	73
11.	M/s Albert David Ltd., Meerut Road, Ghaziabad.	Medicines	300
12.	M/s Elin Electronics Ltd., B.S. Road, Ghaziabad.	Tape Deck Mechanism and Micro Motor 5000 Nos/Day	250
13.	M/s K.R. Food (P) Ltd., B.S. Road, Ghaziabad.	Vanaspati 20 T/Day	250
14.	M/s Superior Vanaspati (P) Ltd., 9.9 of G.T. Road, Ghaziabad.	Vanaspati 30 T/Day	200
15.	M/s Amrit Foods Ltd., G.T. Road, Ghaziabad.	Milk Processing & Ghee	100
16.	M/s U.P. Ceramics & Potteries, G.T. Road, Ghaziabad.	China Wares 2 T/Day	10
17.	M/s Delux Hosiery, B.S. Road, Ghaziabad.	Cotton Cloth Processing 400 kg/Day	50
18.	M/s Addi Industries, B.S. Road, Ghaziabad.	Cotton Fabrics Processing 3 T/Day	200
19.	M/s Surichi Dying & Printing Mills, 9.9 of G.T. Road, Ghaziabad.	Cotton Fabrics Processing 2 T/Day	25
20.	M/s Lion Cycle & Rickshaws Industries, B.S. Road, Ghaziabad.	Mudguards 250 Nos/Day	01
21.	M/s Malik Needle & Allied Products, B.S. Road, Ghaziabad.	Sewing Machine Needle 3 Lacs/Day	03
22.	M/s Surpal Bikes, 9.9 of G.T. Road, Ghaziabad.	Crank Wheel Set & Cycle Rims (5000 Rims/Day)	100
23.	M/s Northern India Cyco Parts, 9.9 of G.T. Road, Ghaziabad.	Cycle Rims 1500 Rims/Day	25

24.	M/s Karam Chand Rubber (P) Ltd., B.S. Road, Ghaziabad.	Cycle Rims 2500 Rims/Day	50
25.	M/s Tele Tubes Electronics Ltd., Kavi Nagar, Ghaziabad.	Picture Tubes 30,000 Nos/month	50
26.	M/s Everest Weaving & Belting Factory, G.T. Road, Ghaziabad.	Fabric Dying 8000 Meters/Day	450
27.	M/s Neelam Enterprises, 9.19 of G.T. Road, Ghaziabad.	Cycle Set 1000 Sets/Day	02
28.	M/s Continental Carbon Ltd., 9.9 of G.T. Road, Ghaziabad.	Carbon Black 5000 MT/Month	1320
29.	M/s Agro India Mills (P) Ltd., 9.9 of G.T. Road, Ghaziabad.	Malted Barley 15 T/Day	90
30.	M/s A.B. Cycle Part (P) Ltd., 9.9 of G.T. Road, Ghaziabad.	Cycle Parts	02
31.	M/s Brij Cottage Industries, 9.9 of G.T. Road, Ghaziabad.	Cotton Bed Sheet & Towel	05
32.	M/s Vimal Organics (P) Ltd., B.S. Road, Ghaziabad.	Bleaching Earth	270
33.	M/s Agarwal Iron & Steel Ind. B.S. Road, Ghaziabad.	Black & G.I. Pipe (20 MT/D)	05
34.	M/s Nipman Fastners (P) Ltd., B.S. Road, Ghaziabad.	Nut Bolts	05
35.	M/s Lakhiya Milk Foods, 9.9 of G.T. Road, Ghaziabad.	Milk Chilling	15
36.	M/s Futuro Components, Hapur Road, Dasna, Ghaziabad.	Cycle Rim 2500 Nos/Day	50
37.	M/s U.P. Board & Containers, Hapur Road, Ghaziabad.	Kraft Paper 1 T/Day	50
38.	M/s Ganga Paper Mills, Hapur Road, Ghaziabad.	Media Craft Paper 18 MT/Day	1000
39.	M/s Al-Nafees Frozen Food Exports Ltd., Hapur Road, Ghaziabad.	Frozen Meat	25
40.	M/s Mohan Meaking & Brewery (Distillery Unit), Mohan Nagar, Ghaziabad.	Alcohol 10 KL/Day	700
41.	M/s National Cereal Products Ltd., Mohan Nagar, Ghaziabad.	Malt	225
42.	M/s Paam Print India (P) Ltd., 30 Loni Road, Ghaziabad.	Dyeing & Printing	425
43.	M/s Alps Industries Ltd., B-2, Loni Road, Ghaziabad.	Dyeing & Printing	50
44.	M/s MSD Dytex (P) Ltd., 5/2, Loni Road, Ghaziabad.	Dyeing & Printing	15
45.	M/s Jhandu Enterprises B-5, Loni Road, Ghaziabad.	Dyeing & Printing	12
46.	M/s Harig India Ltd., Mohan Nagar, Ghaziabad.	Power Lift	02
47.	M/s Reinz Talbros Ltd., 19, Loni Road, Ghaziabad.	Basket Sheet & Jointing	02
48.	M/s Alps Industries Ltd., A-2, Loni Road, Ghaziabad.	Curtains	04
49.	M/s Kathuria Brothers, (Leather Section) A-12, M.R.T.I.A.	Tannery	500
50.	M/s Kathuria Brothers, (Leather Section) A-12, M.R.T.I.A.	Cycle Spokes	500
51.	M/s Marshal Cycles, B-17, M.R.T.I.A.	Cycle Rims	05
52.	M/s Om Enterprises, Near Sihani Chungi	Zn Plating (Job work)	01
53.	M/s Ganga Industries, 7, Pandav Nagar.	Wire Handles & Zn Plating	02

54.	M/s S.S. Enterprises, 363, Pandav Nagar.	Zn, Cr Plating (Job work)	02
55.	M/s Balaji Engg. Works, Pandav Nagar.	Zn, Ni Plating, Cr, passivation	02
56.	M/s Neha Electroplaters, Ghookna Mod, MRT Road.	Zn Plating, Cr, passivation	02
57.	M/s Jiraj Enterprises, Ghookna Mod, MRT Road.	Zn Plating, Cr passivation	02
58.	M/s Five Star Electroplater, Ghookna Mod, MRT Road.	Zn Plating, Cr passivation	02
59.	M/s Unique Electroplating, Ghookna Mod, MRT Road.	Zn, Ni & Cr plating (Job work)	02
60.	M/s Megha Handles, F-13, B.S.R.I.A.	Wire Handles (Zn plating)	02
61.	M/s Agarwal Galvanizing Works, Ghookna Mod, MRT Road.	Galvanizing (Job work)	02
62.	M/s Sun Shine Hosiery, D-24/2, MRT Road. I.A.	Dyeing of Hosiery Cloth	50
63.	M/s Amko Exports, A-1, B.S.R.I.A.	Dyeing of Cloth	50
64.	M/s Shakti Deep Well Hand Pumps, C-160, B.S.R.I.A.	India Mark-2 Hand Pump	05
65.	M/s Tarn International, 9-15, 9.9 of G.T. Road.	C.R. Strips & Hacksaw blades	05
66.	M/s Batik India, Udyog Kunj.	Batik Dyeing of Cloth	10

Source: Regional Office, U.P. Pollution Contrl Board, Ghaziabad.

Table.5.2: Industrial waste water parameters with significant groundwater pollution potential:

	Units	Parameters having groundwater pollution potential
1.	Pulp & papers	Phenol, colour, sulphite, Nitrogen, heavy metals, phosphorous, total dissolved solids.
2.	Steel industries	Cyanide, phenols, iron, tin, Zinc, Chromium
3.	Petroleum refining	Color, copper, chloride, cyanide, Iron, Lead, Zinc, Nitrate, odour, Phosphate, Sulphate, turbidity
4.	Organic chemical industries	Phenols, cyanide, Nitrogen.
5.	Inorganic chemicals alkalies	Aromatics, phenols, Fluoride, Mercury, Phosphate, cyanide, Tin, Lead, chlorine industry, Copper, Aluminum, Barium, Arsenic.
6.	Plastic materials and synthetic industries	Nitrate, Phosphate, organic nitrogen, chlorinated benzenoids and polynuclear aromatics, NH_3, cyanide, Zinc.
7.	Nitrogen fertilizer industry	Sulphate, organic nitrogen compounds, Zinc, Calcium, COD, Iron, pH, Sodium, PO_4.
8.	Phosphate fertilizer industry	Acidity, Aluminum, Arsenic, Mercury, Iron, Nitrate, Sulphate, Uranium, Fluoride, Cadmium.
9.	Electroplating	Cyanide, Chromium, Nickel, Copper, Iron, Cadmium.
10.	Food processing	High BOD, COD, suspended and dissolved organic matter.

Table 5.3: Representative ranges of various inorganic constituents in leachate from sanitary landfill (After Griffen et al., 1976)

Parameter	Representative range (mg/L)
K^+	200-1000
Na^+	200-1200
Ca^{2+}	100-300
Mg^{2+}	100-1500
Cl^-	300-3000
SO_4^{2-}	10-1000
Alkalinity	500-10,000
Fe	1-1000
Mn	0.01-100
Cu	<10
Ni	0.01-1
Zn	0.1-100
Pb	<5
Hg	0.1-10
NO_3^-	10-1000
PO_4	1-100
pH	4-8

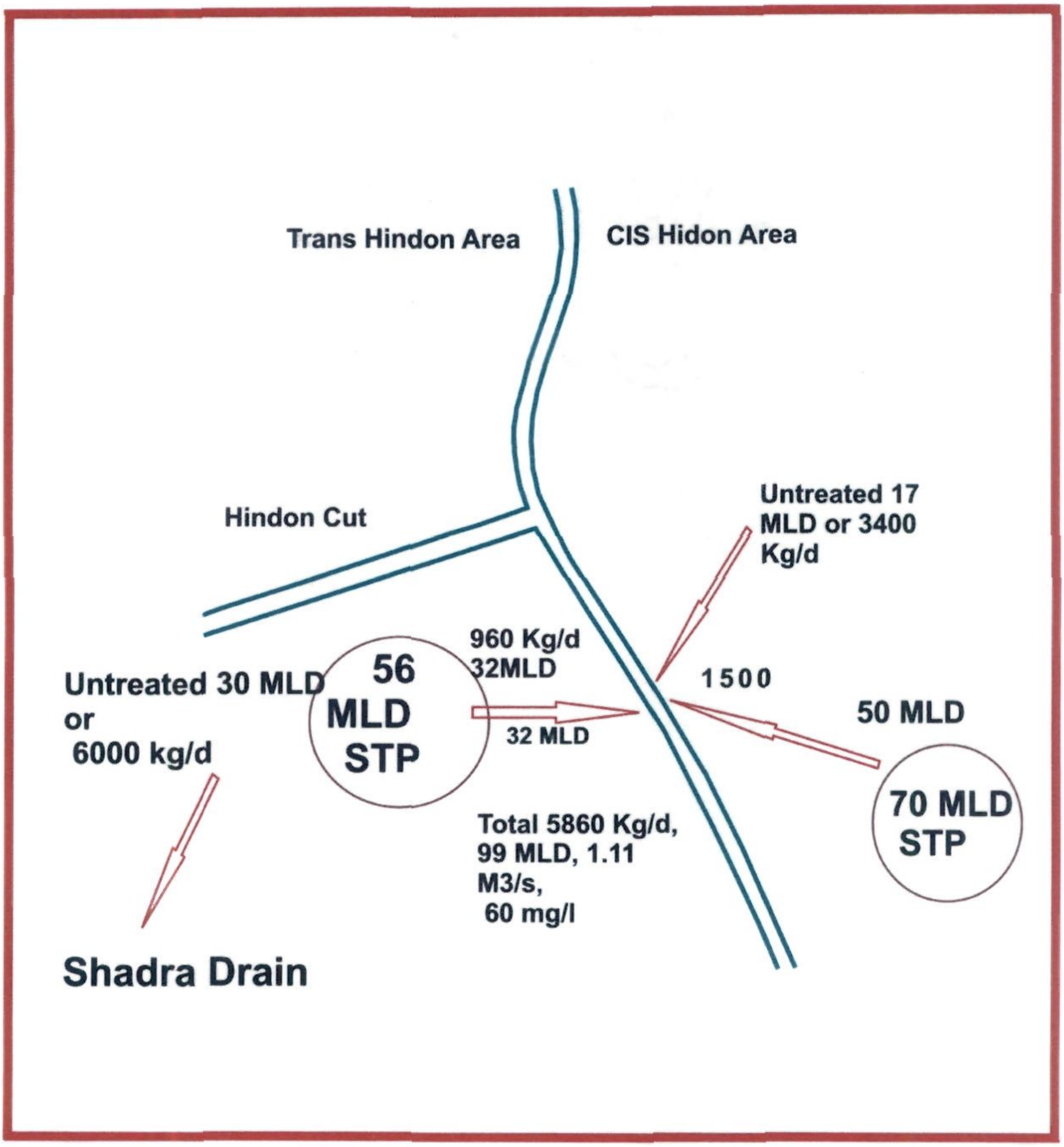

Fig. 5.1: Pollution load at Ghaziabad Town.

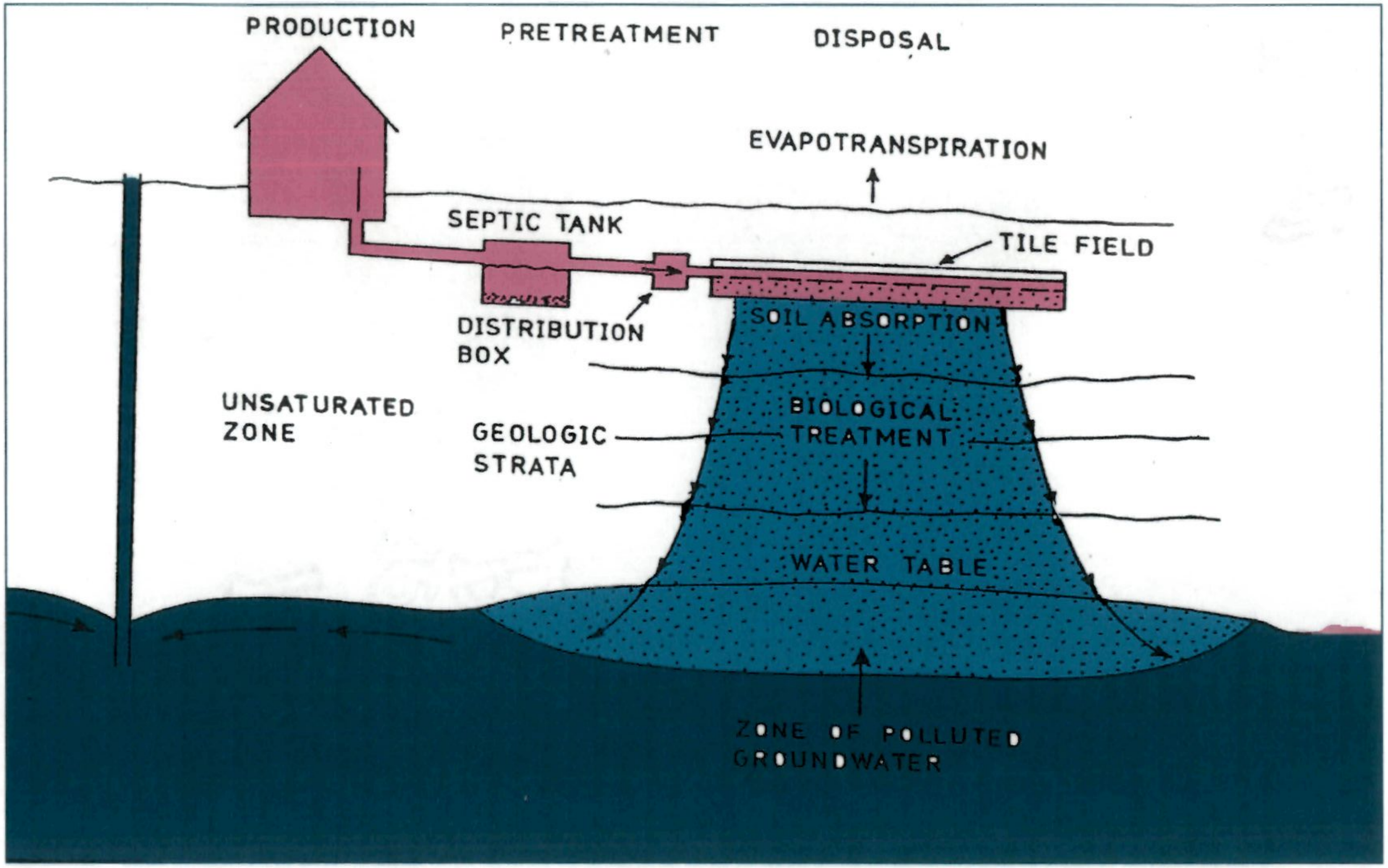

Fig.5.3. Disposal of household wastes through a conventional septic tank system.

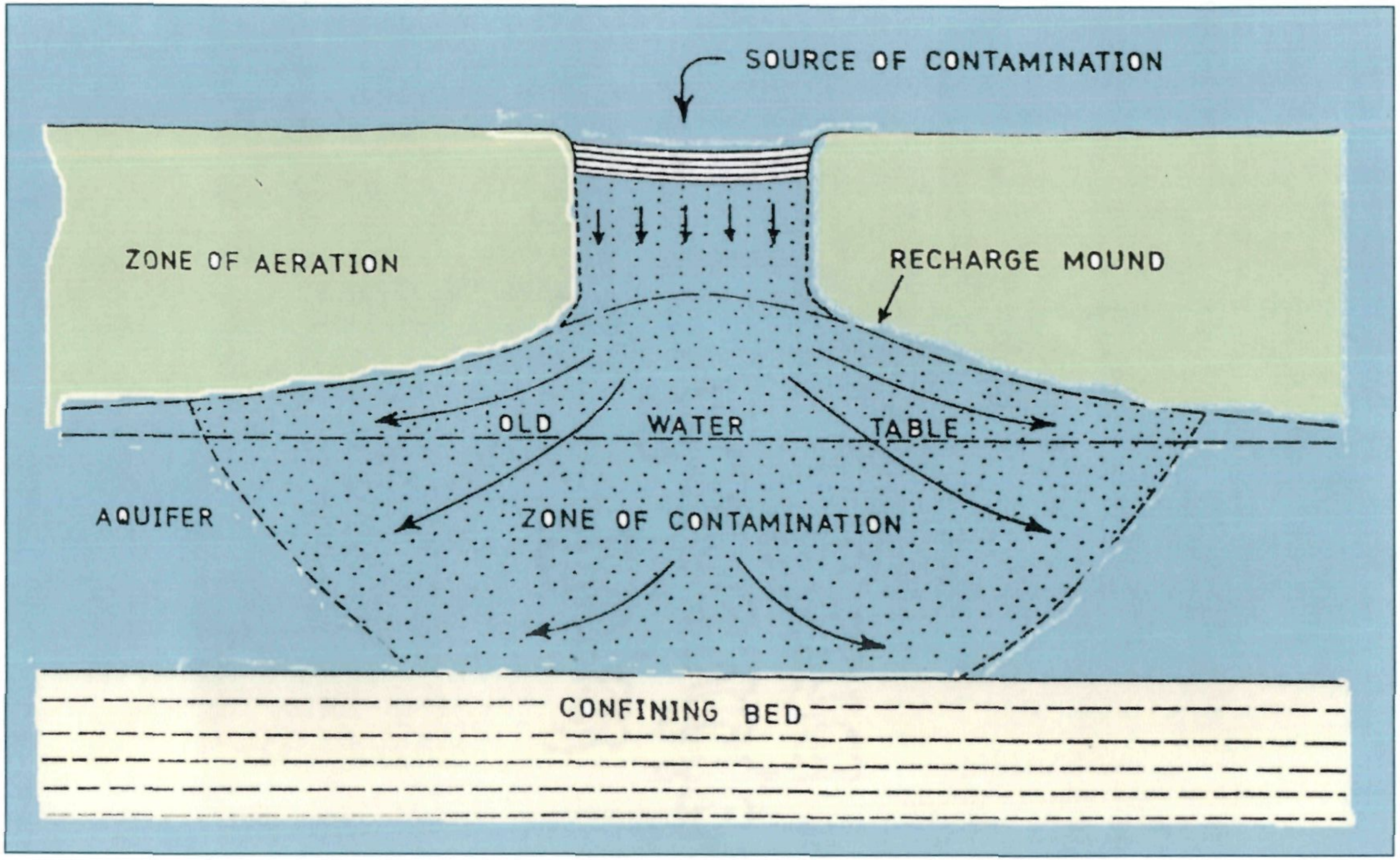

Fig.5.4. Percolation of contaminants from a disposal pit to a water table aquifer.

CHAPTER-VI

GEOENVIRONMENTAL HAZARD IN STUDY AREA

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6.1 Geo-environmental hazards of the area

Ghaziabad-Noida area, is in close proximity of Delhi, exposes a fast developing urbano-industrial scenario, culminating into substantial increase of local and floating population, resulting in high stress on the land – water resource of the area It lies in and adjoining Hindon-Yamuna doab and exhibits a gently undulatory terrain with a gentle slope to the south. The Hindon river in the south looses its base level and develops a common flood plain with Yamuna. The upland areas on either side of the Hindon merge with general level to the south. Palaeo-channels/buried channels, ponds are the other geomorphic features. The area comprises a thick pile of Quaternary to Sub-Recent alluvial sediments. The upland area in general comprises Older alluvium, whereas the Newer Alluvium is confined to narrow tracts of active and old flood plains.

The large tracts of land for agriculture is fast decreasing because of urbano-industrial development. The large cluster of brick kilns have developed an adverse environmental impact in the form of loss of green belts, development of local heat island conditions adjoining brick kilns and industrial areas and loss of aesthetic value and degradation of land.

Ghaziabad and Noida districts of western Uttar Pradesh falling in National Capital Region are the most the densely inhabited regions of the country and agriculture is the dominant economic activity. Based on the prevailing landuse/land cover, the study area has been classified into built-up area, agriculture land, forest land and wasteland. The landuse/land cover pattern is also broadly governed by the geomorphic forms and processes. This inter-relationship of the landform unit and the landuse has been brought out as a separate theme i.e. morpho-landuse map. Degradation of landforms due to natural hazards and influence of anthropogenic activity has also been considered over the variety of landscapes. It has been observed, that different landscapes have different types of environmental problems such as adverse impact of mining in the hilly tracts, flood inundation, bank erosion and water pounding associated with active flood plains and terraces. Water logging and surface encrustation of salts are associated with higher surface of Older Alluvium. The anthropogenic processes including the rapid urbanization (settlement and colonies) and industrialization (growth of major, minor and ancillary industry) in and around Delhi, Ghaziabad, Noida are responsible for modified landform and landuse pattern. This interference with the geoenvironmental system has resulted in a series of imbalances leading to severe geoenvironmental degradation.

Different types of terrain have different geoenvironmental problems. Data suggest that the area is broadly divisible into three important geoenvironmental domains, (i) southwestern part comprising rocky areas with strike ridges and intervening undulating surfaces separated from Yamuna Flood Plain, (ii) Older Alluvial Upland/Surface (a) north of Ghaziabad and (b) south of Ghaziabad and, (iii) Older Flood Plain (Surface/Terraces) of Yamuna and Hindon rivers.

Rocky areas in the southwestern part of Delhi are being extensively used for urbanization. Though, the rocky area is suitable for building purpose and is free from floods, but low groundwater potential is the major problem in the development of this area. In addition, the anthropogenic interference has resulted in deforestation and degradation of rocky areas which has also been responsible for the removal of thin soil cover from these areas.

Large scale quarrying/mining of quartzite for building stone, road aggregate and weathered pegmatite for ceramic clay (near Mahipalpur) has resulted in land degradation. Geoenvironmental impact of quarrying is seen in the form of modification of landuse/landcover, creation of waste dumps, stone dust, air and water pollution, etc. Abandoned quaries have caused large depressions and caves resulting in water pounding. Such degraded areas can be reclaimed by afforestation and developing natural parks. Some of these degradation areas have already been reclaimed and developed into large farm houses in **Gadajpur** and **Mahipalpur** areas by local industrialists.

The Older Alluvial Plain north of Ghaziabad includes predominantly agro-based economy with 79% people engaged in agricultural sector and 85% people living in rural areas. Nearly 95% of the total area is under cultivation which roughly is the total fertile area available for cultivation. Soil fertility in the northern part of the Older Alluvial Surface is generally good. Groundwater constitutes the major source of domestic and irrigation supply. Forest accounts for less than 2% of the area (Revenue and Statistical Department, Uttar Pradesh 1993-94).

Major geo-environmental problem in this area are high moisture/ waterlogging and flooding during rainy season. An area of about 5,567 ha is affected by flooding in Ghaziabad district. Apart from this, some portion in the vicinity of Upper Ganga canal are severely affected by high moisture/ waterlogging due to canal induced seepage. Water table is shallow (3-4 m bgl). This area gets inundated during monsoon. The other includes the degradation of agricultural land into salt land, *usar* (52 sq km) and brick kiln industry (30 sq km). Brick kiln industry is prominently seen on Loni-Baghpat road, Ghaziabad-Meerut road and west of Ghaziabad. Brick kilns have also adversely affected the orchards of the area.

Nearly 1,430 sq km area in southern part of the Older Alluvial Surface (south of Ghaziabad) is severely affected by different hazards.

About 400 sq km is affected by wasteland, brick kiln and other barren land with or without vegetation. Most of the industrial belts (Ghaziabad, Noida, Mohannagar, Dadri, Masna and Sikandarabad) are located in this zone and occupy considerable part (100 sq km approx) of the total area. The different kind of industries, e.g. chemical, glass, plastic, paper, rubber, paints, leather, textile, medicines, detergents, breweries, sugar mills, hydrogenated oils, etc. discharge their effluents in the natural drainage system. This has created alarming industrial pollution in study area.

The high moisture/waterlogged areas (about 700 sq km) in Ghaziabad district is a major geoenvironmental hazard. These are more common in the vicinity of canals which is due to induced seepage from canals. Further, the stagnation of water in the palaeochannel/depression. The problem is further accentuated due to obstructed surface drainage caused by the raised embankments of Upper Ganga canal system. The stagnating water takes a very long time to percolate down or drain off in view of flatness of terrain and low gradient of the streams, and shallow water table in areas (Dadri 2 to 4 m bgl and Sikandarabad 2 to 7 m bgl; Dubey *et al.*, 1991).

A good part of the Older Alluvial Surface between Upper Ganga canal and its main distributary area is degraded into *usar* land. The maximum salt affected area is 52 sq km in Bulandshahr district. The pH value in such areas is above 8.5. Degradation of such agricultural land into salt affected *usar* land around Dadri and Ghaziabad. The southwest of district appears to be the result of canal induced seepage. Excessive canalization and lack of well defined drainage has further resulted in shallowing of water table and high moisture / waterlogging conditions. Shallow water table conditions help in the capillary rise of salt on to the surface and make a thin cover of salt on the soil, causing degradation into sodic soil/*usar* land.

Large areas of the Older Alluvial Surface east of Kali river are highly fertile tracts which are under extensive cultivation and support large settlements. The continuous withdrawal of groundwater for irrigation has resulted in lowering of groundwater table by about 6-7 m in the last decade (Hapur-Babugarh area).

The Older Flood Plain/terraces of Yamuna and Hindon river in general are prone to periodic waterlogging and flooding during heavy rains. The palaeocourses get rejuvenated and start flowing dangerously through existing colonies. Fluvial landforms are well developed on either side of Yamuna, Hindon and Kali rivers in the alluvial deposits covering northern and eastern part of Delhi and adjoining areas in Ghaziabad, Meerut and Bulandshahr districts. Fluvial landforms include rivers/stream (channels), point bars, palaeochannels, cut off meanders/ox bow lakes, abandoned channels, inland depressions etc. The confluence of Yamuna and Hindon river has migrated upstream several times in the past as is evidenced by the presence of abandoned channels and palaeochannels. North-northeasterly drainage in southern parts of Delhi and upstream migration of confluence of Yamuna and Hindon river may possibly be due to northward tilting of southern block.

Different kinds of industries situated in the NCR region dispose off their effluents into line/unlined drains and natural drainage system (Yamuna and Hindon rivers) of the region. The soil of the area is so loose and bear a low strength and not allowed for heavy construction work. Although, the man made embankment/barriers on these rivers have helped in reclamation of large areas in the neighbourhood of urban centres at the cost of agricultural land in rural areas, but these areas still remain prone to waterlogging during and after heavy rains. In spite of this, these land surfaces have been extensively utilized for large scale housing and industrial complexes (covering an area of 55 sq km approx in Noida, Ghaziabad, etc.) with environmental degradation to its proneness to natural hazards.

The large parts of eastern terrace of Hindon river are badly affected by natural hazards, i.e. high moisture / waterlogging, swamps and palaeochannels (exhibiting characteristic anastomotic drainage pattern around Kasna, Gharbara, Mursaidpur, Jaganpur Hawa, Atta Gujran and east of Dankaur). This has rendered most part of the area uncultivable due to seasonal flooding. The construction of embankment/bund extending from Kasana to Fatehpur-Atta has helped in reclamation of a larger part of the area into agricultural land, built-up area, industrial area, but it remains prone to high moisture/waterlogging due to induced seepage from the river bed, rejuvenated palaeocourses and obstructed surface drainage due to raised embankment. Further, this has increased the siltation and flood prone areas north of Surajpur. Considerable part of the Kasna still remains high moisture / waterlogged with a number of palaeochannels which get reactivated during monsoon period causing surface inundation in this area.

6.2 GEO-ENVIRONMENTAL HAZARDS DUE TO SANITARY LANDFILL SITE AT GHAZIPUR:

The sanitary landfill as defined by the American Society of Civil Engineering is a method of solid-waste disposal that functions without creating a nuisance or hazard to public health or safety. Engineering principles are utilized to confine the waste to the smallest practical area, reduce it to the smallest practical volume, and cover it with a layer of compacted soil at the end of each day of operation, or more frequently if necessary. It is the covering of the waste with compacted soils that makes the sanitary landfill "sanitary." The compacted layer effectively denies continued access to the waste by insects, rodents, and other animals. It also isolates the refuse from the air, thus minimizing the amount of surface water entering into and gas escaping from the wastes.

The depths of landfills vary from about 2 to 13 meters. Normally, refuse is deposited, compacted, and covered by a minimum of 15 centimeters of compacted soil at the end of each day. The area show 1 to 4 cover ratio is common, that is, 30 centimeters of soil for every 120 centimeters of compacted waste. The finishing cover is at least 60 centimeters of compacted soil designed to minimize infiltration of surface water. The most significant possible hazard from a sanitary landfill is groundwater or surface-water pollution. If waste buried in a landfill comes into contact with water percolating down from the surface water or groundwater moving laterally through the refuse, obnoxious, mineralized liquid capable of transporting bacterial pollutants called *leachate* is produced. The nature and strength of the leachate depend on the composition of the waste, the length of time that the infiltrated water is in contact with the refuse, and the amount of water that infiltrates or moves through the waste. An average a city in India generates 0.27 (0.11 to 0.08) kg of solid waste per day so, that the 109 million people concentrated in urban centers produce approximately 10.75 million tonne of solid wastes of garbage and other materials. Delhi produces about 8000 tonnes per day, in the rural areas. The solid wastes produced is predominantly agricultural, and wholly disposable as organic manure for the fields. Between 51000 and 71500 tonnes daily or 18.6 to 26.1 million tonnes annually of human faeces are deposited in the fields in the rural areas (Deodhar and Nath,1993). The third category of wastes generated includes mining wastes and spoils. The generation of thermal power involves production of huge quantities of ash (30-40% of the coal used). All our thermal power plants produced 16.6 million tonnes of ash, some of which contained toxic elements such as Zn (6%), Ba (12.2%), Cu (1.2%), As (0.02%), Va (0.08%), Mn (0.2%), etc. Likewise, the fertilizer plants generated huge quantities of wastes (containing phosphorous gypsum) – 3.5 million tonnes. 80% of this waste released into the ecosystem.

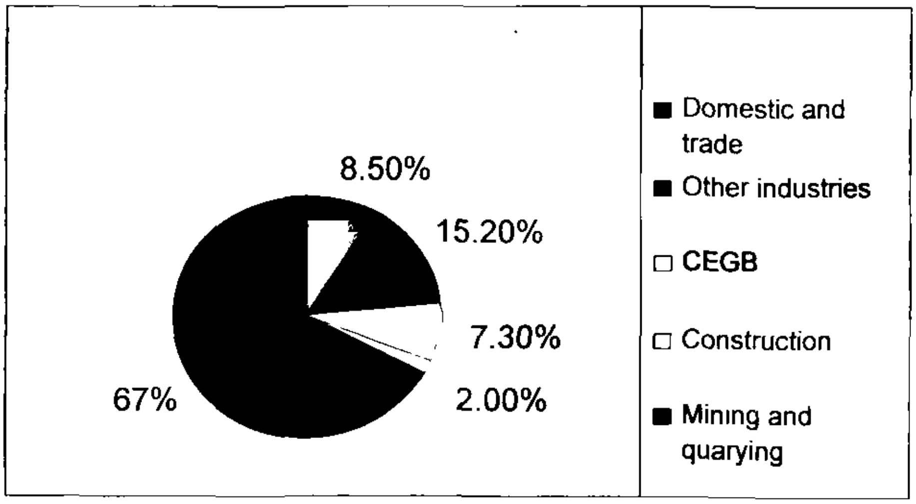

Fig.6.1. The global annual production of solid waste

6.2.1 Description of Ghazipur Sanitary Landfill

This Sanitary Landfill (SLF) site is situated near fish and egg market on National highway number 24 in the Trans-Yamuna area. The area of site is about 70 Acres.

Sanitary Landfill is to bury refuse containing biodegradable and Non-biodegradable material in a systematic and hygienic way without exerting any nuisance or hazard to public health. The biodegradable portion of the refuse undergoes anaerobic decomposition over a relatively long period of time and produce gases, such as methane (CH_4) and Corbon dioxide (CO_2).

Sanitary Landfill operations are usually performed by depositing refuses in a natural or man made depression or dumping it at round level, compacting it to the smallest practical volume and covering it with compacted earth in a systematic and Sanitary manner.

Details of the site

Area	-	70 Acres
Deep	-	3 m. Total Filling 6m.
Daily Filling Material	-	2000 Metric ton
Timing Hours	-	24 Hours
Machinery of Area	-	Bulldozer High Excavator Loader
Future settlement	-	Garden, Electric Generation

6.2.2 Type of Wastes

The wastes disposed by the sanitary landfilling method are municipal refuse, trees, shrubs and grass, street sweepings, demolition and constructions wastes, non-toxic, industrial wastages, dead animals, hospital wastes, animal husbandry wastes and such other materials. Oil, Solvents, Volatile, Solids and Sludges and other hazardous wastes must be avoided as far as possible.

6.2.3 Process

The process basically consists of laying the waste material in a planned and methodological manner, dumping than compacting and finally covering it with soil. The soil cover tends to remove common landfill odour and keep away flies, rats and other vectors from thriving on the wastes.

The thickness of the wastes layer spread and compacted before covering with soils ranged from 0.6m to 2.4m depends on the methods used.

6.2.4. Landfilling methods:

There are two types of method are

(i) Conventional Method for dry areas.

(ii) Conventional Method for wet areas.

(i) Conventional Method for dry areas.

The conventional method again sub divided into following-

- **Area method:** This method is used in areas where natural depression exists. Soil cover is obtained by cutting down fill areas. The waste is put in the depression and compacted and covered. The process is repeated till the depression is filled up .

- **Trench Method:** This method is used in flat and rolling areas. A trench 2m deep and 5m wide is excavated. Solid waste is placed in the trench and the excavated earth is used as cover soil.

(ii) Conventional Method for Wet areas

Swamps and marshes, tidal areas and ponds and pits are typical wet areas that have been used as landfill sites. Because of the problems associated with contamination of local ground waters.

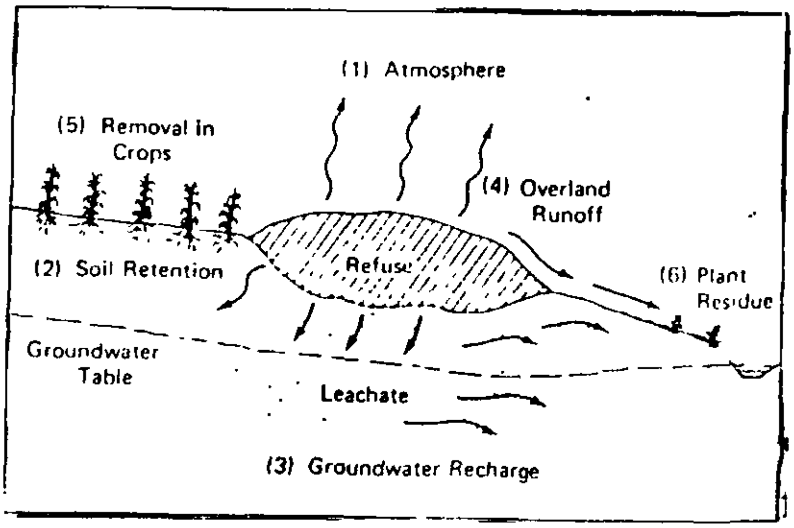

Fig.6.2. Sanitary Landfill site in a Semi Arid environment.

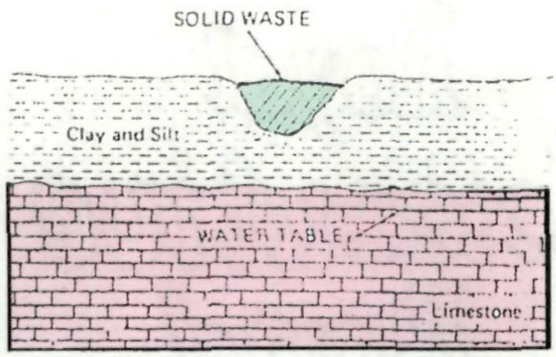

Fig.6.3. Landfill site in a Humid environment waste is buried above the water table in relatively impermeable environment.

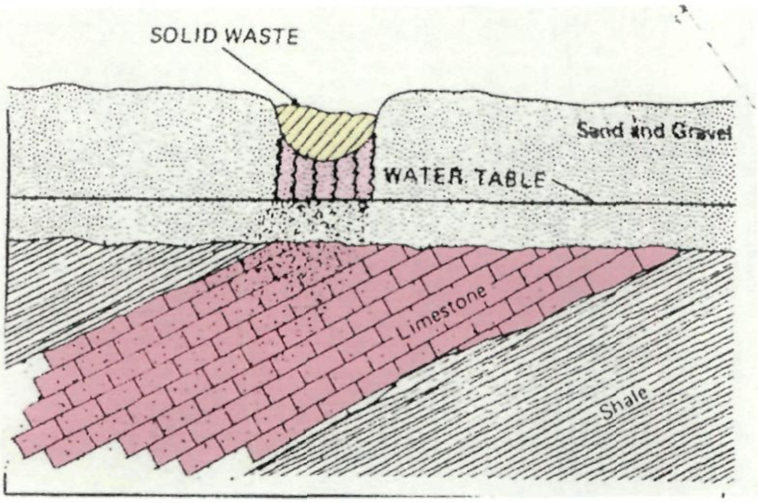

Fig.6.4. waste disposal site where the refuse is buried above the water table over fractured rock aquifer.

6.2.5 Leachate in landfills

Leachate may be defined as liquid which has percolated through solid waste and has extracted dissolved or suspended materials from it. In most landfills the liquid portion of the leachate is composed of the liquid produced from the decomposition of the wastes and liquids that has entered the landfill from external sources, such as surface drainage, rainfall, ground water and water from underground springs.

When leachate percolates through solid wastes that are undergoing decomposition, both biological materials and chemical constituents are picked up.

The factors influencing the production of leachate from a landfill site are:

(a) The initial refuse moisture content.

(b) The volume of rainfall allowed to enter the landfill.

(c) The volume of other liquids deliberately added to the refuse

(d) Waste composition and density.

The leachate is being formed, it under go physical, chemical and biological attenuation, thus resulting in reduction of polluting species in leachate. It is found that a sufficient layer of clay is available on the bottom of Sanitary Landfill, Ghazipur.

The leachate is often produced before the field capacity of the refuse is reached due to channeling in the heterogeneous mass. The composition of leachate can vary from one site to another site and is influenced by the age of landfill and the type of biological activity within it.

The high values would be typical of freshly leached refuse. Migration of water through the fill would favour ready decomposition of the putresible fraction in particular to give high concentration of fatty acids with low pH. The low values would be more typical of leachate from landfill which are several years old, and the most of the soluble materials had already been leached from the refuse.

Table 6.1. Range of chemical composition of landfill leachate Component:

Component	Quantity mg/dm^3
Total Organic Carbon	256-28,000
pH	3.7-8.5
NH_4	0.0-1106
NO_3	0.2-10.3
PO_4	6.5-8.5
SO_4	1.0-1558
Cl	4.7-2467
K	28-3700
Na	0.0-7700
Mg	17-15,600
Fe	0.0-2820
Mn	0.09-125
Ca	50-7200
Cd	0.03-17
Pb	0.10-2
Cu	0.0-9.9

6.2.6 Gases in landfill

Gases found in landfills include air, ammonia, carbon dioxide, carbon mono-oxide, hydrogen, hydrogen sulfide, nitrogen and oxygen. Carbon dioxide and methane are the principal gases produced from the anaerobic decomposition of the organic solid waste components.

The recovery of Methane gas has been carried out from Sanitary Landfill site of Ghazipur in sufficient quantity. The project for recovery of Methane gas from Sanitary Landfill sites, Methane is being carried out in sufficient quantity which may later be used for the production of electricity. Wells are drilled into the landfill, each well having a radius of influence of about 50m are linked by pipe work to central pumping and transmission station where as much water as possible is removed from the gas prior to its transmission to the utility. The calorific value of landfill gas is directly related to its methane composition. Landfill gas with the Methane content of 50% by volume would thus have a calorific value of 15 Ka/m^3. The methane concentration gas varies from about 65% for gas drawn from the landfill to 25% CH_4 for gas drawn from the landfill. perimeter. The average gas yield from a landfill is 364 m^3/t. The gases are utilized for directing heating, electricity generation and CO_2 removal. To monitor the effect of landfill on the water quality due to pollution from various kind of wastes, for this purpose, several peizometers have been installed in and out of the landfill site. At present the ground water quality of these wells is unsatisfactory and indicate sign of major pollutant in the water around the sanitary landfill.

Table 6.2: Chemical results Samples around Ghazipur Sanitary Landfill Site

Source	HP	HP	HP
Major ions	Sample 1	Sample 2	Sample 3
pH	6.54	8.6	8.2
EC	3100	2500	2800
TDS	1984	1600	1792
Hardness	52	300	375
Ca	317.43	14.42	76.15
Mg	59.44	64.32	45.05
Na	120	29	320
K	6	2	26
HCO_3	0	235	162
CO_3	78	52	145
Cl	443.04	128.8	431.68
SO_4	609.02	209	165

Table 6.3. Trace element concentration at landfill site.

Samples	S1	S2	S3
Fe	0.122	0.330	0.250
Mn	0.114	0.150	0.075
Pb	0.020	0.050	0.098
Cu	0.098	0.108	1.240
Zn	1.060	0.236	1.032
Cd	0.012	NIL	NIL
Cr	NIL	NIL	NIL

Table.6.4. Parameters for landfills.

Biodegradable	38.60% (AV)
Paper	5.57% (AV)
Plastic	6.03% (AV)
Metal	0.23% (AV)
Glass and Crockery	0.99% (AV)
Bio resistant (Leather, Rubber, Bones Other Synthetic material)	13.87% (AV)
Inert i.e. (Stones, Bricks, Ashes)	34.71% (AV)

T able.6.5.Chemical characteristics of mixed municipal solid waste:

Moisture	43.65% (AV)
Organic Carbon	20.47% (AV)
Nitrogen	0.85% (AV)
Phosphorous as P2O2	0.34% (AV)
Potassium as K2O	0.96% (AV)
C/N ratio	24.08% (AV)
Calorific Value	712.50 Koal/Kg (AV)

Plate 1. Unauthorized development of new colonies on the flood plain of Hindon river.

Plate 2. Improper dumping of industrial waste out side the factories.

Plate 3. Shaibad drain and Lohia drain serves the effluent discharge from industries.

Waste land at Gaziabad

Plate 4. Dumping of industrial waste near the agricultural land.



Plate 5. Degradation of land due to Brick Kline industries.

Plate 6. Industrial waste dumping at Noida Industrial Belt.

Plate 7. Flooding during heavy rainfall near the flood plain of Hindon.

Plate 8. Degradation of agricultural land due to rapid urbanization

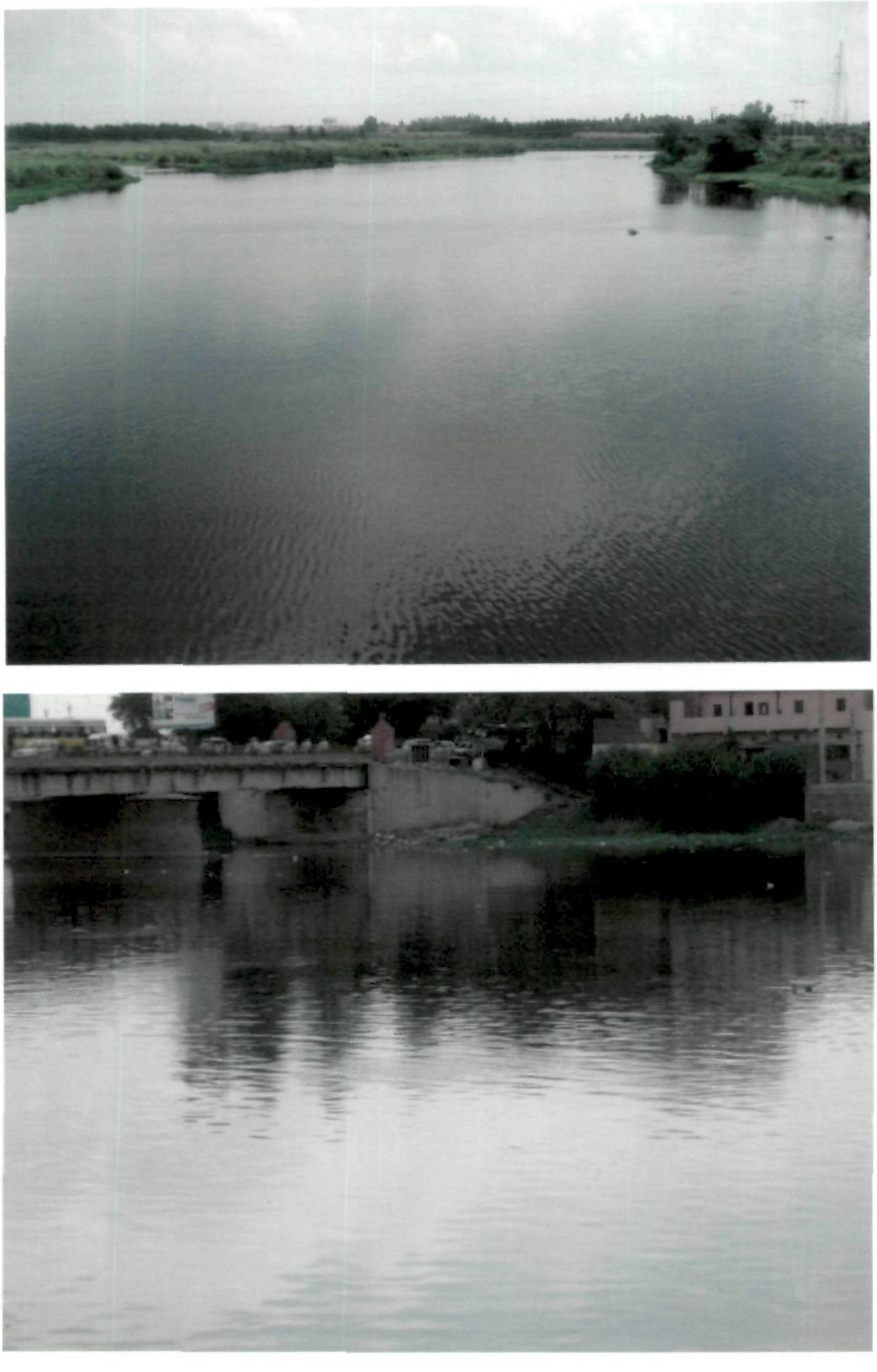

Plate 9. Black water of Yamuna river showing the pollution level in the river.

Cremation center at the bank Hindon river

Plate 10. Industrial effluent drain meet at Hindon river.

Plate 11. Water logging area around Ghaziabad and Noida.

CHAPTER-VII

HYDROCHEMISTRY

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7.1 INTRODUCTION

Water is frequently referred as universal solvent, because it has the ability to dissolve at least some amount of all substance that comes in contact. Rainfall and snow melt percolating through the soil zone and unsaturated material chemically reacts with the gases, minerals and organic compounds that occur naturally within the subsurface. These reactions continue below the water table as the water flows through the aquifer. The result is that the characteristics and composition of the water evolve as it flows through the ground in response to the types of solids and gas phases that the solution encounters and the geochemical reactions that occur between these phases (Deutch, 1997). Therefore, each groundwater system has its own characteristic chemical signature produced as a result of chemical alteration of the meteoric water recharging the system (Drever 1982; Back 1996).

There is considerable literature on the interpretation of geochemical processes in groundwater based on hydrochemical data and model simulations of hypothetical reactions. Geochemists have evaluated redox reactions and the partial equilibrium concept in aquifer in which chemical evolution is driven by one or more concurrent irreversible reactions. Carbonates, primary silicates, clays and sulfide minerals, ion exchange and organic carbon reactions play important role in driving chemical evolution in these systems (Deutch 1997).

The chemical composition of groundwater varies within the wide limits (Faure 1998). However in most of the inland areas of the Indian subcontinents; it is the Ca-Mg-HCO3 type (Bartarya 1993; Datta and Tyagi 1996; Bhatt and Saklani 1996). The chemical alteration of the meteoric water depends on several factors such as interaction with solid phases, residence time of groundwater, mixing of groundwater with pockets of saline water, and anthropogenic impacts (Stallard and Edmond 1983, Dethier 1998, Faure 1998, Subba Rao 2001). Broadly speaking, the intake of major and minor cations is related to solid-water interaction (Bartarya 1993; Subba Rao 2001). Such a direct relationship between lithology and relative abundances of cations is easily discernible in hard-rock areas (Faure 1998), for example, in carbonate rock terrain Ca+Mg>Na+K, whereas it is reversed in areas with arenaceous and crystalline lithologies. In dealing with a groundwater system in alluvium-covered areas, on the other hand, straightforward clues may not be as simple due to the masking of normal chemical alteration trends by anthropogenic influences.

The study of a relatively large group of samples from a given area offers clues to various possible trends of chemical alteration which the meteoric water undergoes before acquiring distinct chemical characteristics and attaining a chemical steady state in the aquifer. These identified trends in turn may be related to natural and anthropogenic causative factors. With this simple objective in sight systematic sampling was carried out in the study area from the point of view of understanding various possible sources of dissolved ions and to assess the seasonal variation in groundwater quality with respect to drinking and irrigational uses.

7.2 METHODOLOGY

7.2.1 Sample Collection

The objective of sampling is to collect a portion of material small enough in volume to be transported conveniently and handled in the laboratory while still accurately representing the material is being sampled (APHA 1992). Samples, however, have to be handled in such a way that no significant change in composition occurs before the test are made.

Due to probable seasonal variation in the water quality, in all, one hundred twenty groundwater samples were collected for physico-chemical analysis in two successive seasons viz. Pre-monsoon and Post-monsoon period corresponding June 2006 and November 2007, respectively. Out of 120 samples, 60 samples were collected in June 2006 and 60 samples in November 2007 from the same sampling sites. The water samples were collected and stored in 1 litre capacity clean plastic bottles. Before collection the bottles were carefully washed. In order to avoid any impurity, the wells were duly pumped so that the stagnant water is completely removed from storage with in the well assembly. Besides major ions, 60 groundwater samples were also collected in June 2007 for trace element analysis. The trace element samples were treated with 0.6N HNO_3. Sampling location map of the study area is shown in Fig. 7.1.

The major ion and trace elements analysis have been carried out in the Geochemical laboratory, Department of Geology, Aligarh Muslim University, Aligarh.

7.2.2 Analytical Techniques

The physico-chemical characteristics of water samples were determined according to the standard methods of APHA (1992). Electrical Conductivity (EC) and pH were determined in the field. pH by a portable digital pH meter. The EC was measured with the help of portable kit with electrodes.

The concentrations of Ca^{++}, Mg^{++}, HCO_3^-, Cl^- and total hardness were determined by titrimetric method. Ca^{++} and Mg^{++} determined by

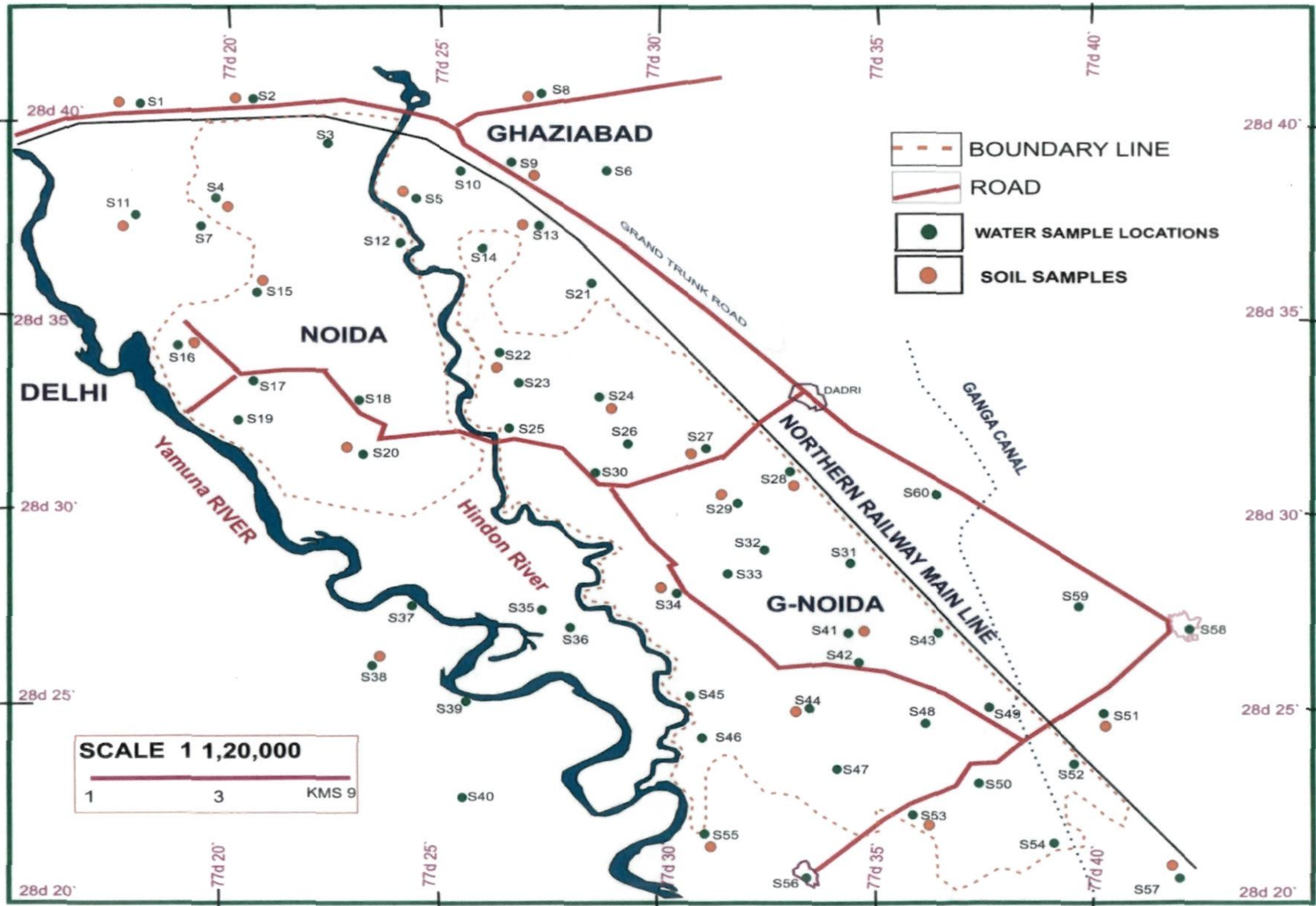


Fig.7.1.Sampling location map.

EDTA titration, for HCO_3^-, HCl titration to a methyl orange point was used. Chloride also determined by titration with $AgNO_3$ solution. Flame emission photometry was used for the determination of Na^+ and K^+. In this method water sample is atomized and sprayed in to a burner. The intensity of the light emitted by a particular spectral line is measured with the help of a photoelectric cell and a galvanometer. Sulphate analysed by gravimetric method. The concentrations of NO_3^- determined with the help of nitrate spectrophotometer.

The trace elements like Cu, Zn, Ni, Fe, Mn, Cu, Cr, Cd and Pb were analysed by Atomic Absorption spectrophotometer. The analyzed data of the data of the pre- and postmonsoon 2006 and 2007 water samples are given in Appendix VII-A, VII-B and VII-F.

7.3 GROUNDWATER COMPOSITION

Inorganic constituents are classified as major constituents with concentration greater than 5 milligram per litre (mg/l), minor constituents with concentration ranging from 0.01 to 10 mg/l and trace element with concentrations less than 0.01 mg/l (Davis and Dewist 1966).

Precipitation and infiltration process serves as an important factor of the overall chemical characteristics of the groundwater in an unconfined aquifer. The soil zone that support plant life is one of the most important components in the study of groundwater chemistry. It is in the soil zone that water first enters and come in contact with inorganic and organic solids.

Naturally occurring dissolved organic compounds are typically present in minor or trace quantities. By far the most abundant organic compounds in shallow groundwater are humic and fulvic acids. The important groundwater gases include oxygen, carbon dioxide, hydrogen sulfide and methane. Organic carbon in the soil also effects the inorganic chemistry of groundwater because the oxidation of organic matter produces CO_2 gas. Carbon-dioxide gas reacts with the water to produce carbonic acid and the other inorganic carbon species like bicarbonate and carbonate. The production of carbonic acid makes the water a more aggressive weathering solution and the increase in the level of anionic carbon species enhances ion complexation (Deutsch 1997).

$$O_2 + \mathrm{OM} \rightarrow CO_2$$

$$\mathrm{H_2O{+}CO_2} \rightarrow H_2CO_3$$

$$H_2CO_3 \rightarrow H^+ \equiv HCO_3^-$$

Rainwater and melted snow in non-urban, non-industrial area has pH values normally between 5 and 6. Because the water must be acidic, it is apparent that HCO_3 is the only ionic species of dissolved inorganic carbon present in a significant amount (Freeze and Cherry 1979).

The main source of sulphate is the industries from where Sulphur is spewed in to the atmosphere. Emission of Sulphur into the atmosphere occurs mainly as particulate S and gaseous SO_2. In the atmosphere this leads to increased concentration of H^+ and SO_4^{2-} in rain water, as shown in following reactions

$$S + O \rightarrow SO_2\,(g)$$

$$SO_2\,(g) + H_2O + \frac{1}{2}\,O_2 \rightarrow SO_4^{2-} + 2H^+$$

In conclusion, it can be stated that rain water is extremely dilute, slightly to moderate acidic oxidizing solutions that can quickly cause chemical alterations in soil or in geologic materials in to which it infiltrate (Freeze and Cherry 1979).

7.4 SOIL SAMPLING PROCEDURE

For the collection of soil sample, polythene bags of 1 kg. Capacity is used. A trenching spade is convenient tool for sampling surface soils. Soils should be free of moisture before storing for long period of time. To make the soil free of moisture, it should be kept in an oven at a temperature of 120°C for ten hours. The analyzed data of major ions and trace elements are given in appendix VII-G and VII-H.

7.5 CHEMISTRY OF MAJOR IONS

7.5.1 Hydrogen ion concentration (pH)

Hydrogen ion concentration in water is the logarithmic reciprocal of their weight, measured in gram per litre of water. On other words pH value of water is a measure of acidity and alkalinity of water and is very important indicator of its quality. It influences the growth of plant and soil organism, therefore, it affects to a greatėr extent the suitability of water for irrigation. The pH value of acidic water varies from 0-7 and alkaline water between 7-14, while neutral water has a pH value of 7.0. Mostly the fresh waters have a pH of 6-8. The highest desirable limit for public water supply is 7 to 8.5 while maximum permissible limit is 6.4 to 8.6 (WHO, 1993). The pH value of the area pre-monsoon ranges from 6.2-9.6 with an average of 7.89, and in post-monsoon 6.1-9.6 with an average of 7.8, thereby showing slightly alkaline nature of water.

7.5.2 Electrical conductivity (E.C.)

Electrical conductivity is the ability of a substance to conduct an electric current. Electrical conductivity of water is directly related to the concentration of ionized substance in water. It gives an idea about extent of mineralization and is indicative of the salinity of water. The electrical conductivity with 400 µS/cm at 25°C is considered suitable for human consumption. The water samples in the study area are characterized by high extent of mineralization at a few places. The pre-monsoon value ranged between 150-2700 μS/cm, post-monsoon value range between 500-2800 μS/cm

7.5.3 Total dissolved solids (TDS)

Total quantity of chemical constituents present in the water known as total dissolved solid. TDS is an important criteria which measures the suitability of water for irrigation. The permissible limit of total dissolved solid is 1000 mg/l (WHO, 1993). Majority of the samples in the study area were found to have the concentration of TDS more than 1000 mg/l. The value of TDS ranges between 96 to 1792 with an average of 854.93 mg/l (Fig. 7.2-A). The higher concentrations of TDS have been recorded from Sikandrabad (1728mg/l, 1792 mg/l) Rajpur Khurd (1600 mg/l, 1664 mg/l), Kotderi (1408 mg/l, 1344 mg/l) and Pali (1344 mg/l, 1472 mg/l). Water with high concentration of TDS is laxative effect on people.

7.5.4 Total Hardness

Hardness of water is related to its capacity to produce leather from soap. The hardness is caused by the presence of carbonates of calcium and magnesium, chloride and sulphate of calcium and magnesium. Water has been classified as hard or soft according to their action on the soap. The less amount of soap is consumed to produce leather when the water is soft. Public acceptability of the degree of hardness of water may vary considerably from one community to other, depending upon local conditions. On the basis of hardness, water is classified as follows:

1.	Less than 50 ppm	: soft
2.	50 to 100 ppm	: moderately soft
3.	100 to 150 ppm	: slightly hard
4.	150 to 250 ppm	: moderately hard
5.	250 to 350 ppm	: hard
6.	More than 350 ppm	: excessively hard

The hardness of water in the study area ranged from 221.14 to 498.78 mg/L (pre-monsoon) and 173.66 to 466.97 mg/L (post-monsoon). With an average of 356.05 mg/L and 319.37 mg/L. In general, water of the area is hard. Maximum value was recorded at Khodna Khurd (498.78 mg/L) in pre-monsoon. The maximum permissible limit of hardness for drinking water supply is 500 mg/L. Ground water of the area is with in the permissible limit. Hard water is generally believed to have harmful effect on human being. Cardiovascular diseases are reported to be confined to the areas of soft water than to those having hard water (Crawford, 1972).

7.5.5 Chloride (Cl)

Sodium and calcium chloride are found in natural water but are harmful to fish in high concentration. Although chlorides may be injurious to people suffering from diseases of heart and kidney. WHO, 1993 recommended 250 ppm as desirable limits of chloride in potable waters whereas the Indian Council of Medical Research (I.C.M.R. 1975) recommends 200 mg/L as desirable limits and 1000 mg/L as maximum permissible limit. The major sources of chloride in ground water are seepage from sewage, industrial effluents and chloride brought down by rainfall.

The chloride concentration in the study area ranged from 98 to 412.6 mg/L with an average 228.94 mg/L in the pre-monsoon and 16 to 392 mg/L with an average 211.18 mg/L in post-monsoon water samples. High concentration of chloride is recorded in Bahlapur (412.6 mg/L and 392 mg/L) and in ground water of Mandaoli, Chiplyana Buzurg, Bhopani and Manhpur. In rest of the samples, the chloride concentration are within the permissible limit. A high concentration of chloride gives salty taste to water and large amount effect corrosively on metal pipes. People who are not accustomed to high chlorides in water are subjected to laxative effect as suggested by Raviprakashan and Krishna Rao (1989).

7.5.6 Calcium (Ca)

Calcium is one of the important cations present in ground water. The main sources of calcium in ground water are rain water, leaching from fertilizers, soil amendment, weathering of calcium silicate minerals and use of surface water for irrigation. The dissolved CO_2 generally controls the calcium ion. The maximum desirable limits of calcium in drinking water is 15 mg/L (WHO 1993). Calcium contents in ground water of the area ranged from 30.5 to 86.8 mg/L in pre-monsoon and 27.7 to 85.6 mg/L in post-monsoon. The maximum permissible limit is 200 mg/L. The high concentrations of calcium were observed at Ghori Bachera. The concentration of calcium in the area is less than 200 mg/L. Calcium has tendency to get precipitated in the form of concentrations known as kankar. During contact with clays, part of calcium may also undergo ion-exchange reaction, that may be the reason for the depletion of calcium in ground water.

Calcium is an essential constituent for human body which requires 0.7 to 2.0 g/day. However, large doses are required by pregnant women and growing children. In human body it is essential for mascular and nervous system, cardiac function and in coagulation of blood. Low levels of calcium may have adverse effects on human health. Higher content is also harmful resulting in the function of kidney and bladder stones and irritation in urinary passage.

7.5.7 Magnesium (Mg)

Magnesium is common, moderately toxic element and is found in almost all water supplies. If high concentration of magnesium is combined with sulphate a laxative effect result, therefore some caution must be exercised with it. Magnesium is also a constituent of hardness. The permissible limit of magnesium content for drinking water varies from 50 mg/L (WHO, 1993) Indian Council of Medical Research (ICMR,1992) has prescribed 50 mg/L as maximum desirable limit and 100 mg/L as maximum permissible limit.

Magnesium contents in groundwater during pre-monsoon period range 30.4 to70.8 mg/l and post-monsoon 22.6-65.6 mg/l with an average of 50.07 mg/L in pre and 62.6 mg/L in post-monsoon. Relatively higher concentration of magnesium have been observed at Khod khurd, Surajpur and Manhcha. In other part of the area Mg contents are less than 50 mg/L. Magnesium deficiency is associated with structural functional changes and may cause severe diarrhoea, chronic renal failure and protein-caloric malnutrition (WHO, 1993).

7.5.8 Sodium (Na)

Sodium is present in nearly all natural water and its concentration in ground water depends on hydrogeological conditions, industrial activities and weathering of rock minerals present in soil. The most important water quality aspect of sodium is the possibility of changing the permeability of soil. The sodium concentration in the area ranges from 114 to 556 mg/L in pre and 8 to 532 mg/l, post-monsoon with an average of 248.9 mg/L (pre-monsoon) and 235.91 mg/L (post-monsoon). The highest value of Na has been recorded at Bulandshahar Road Industrial Area (556 mg/L) and Lal Kuan Industrial Area (518 mg/L). The guideline value of sodium is given as 200 mg/L which is based on taste consideration (WHO, 1993).

Though sodium is an essential element for human body, its higher content in drinking water may be harmful to a person suffering from cardio and renal diseases pertaining to circulatory system.

7.5.9 Potassium (K)

The concentration of potassium in the area is under the permissible limit, ranging between 12 to 88 mg/L in pre-monsoon and in post-monsoon 8 to 82 mg/l with an average of pre-monsoon (42.21 mg/L) and post-monsoon (38.0 mg/L). The higher values, of K has recorded at Astaula, Meerut road industrial area and Blaspur. The maximum permissible limit of potassium is 12 mg/L (WHO, 1993). The depletion of potassium may be as a result of reaction with clay minerals. The sources of potassium contamination in groundwater is mainly rain water, and also the use of potash fertilizer, and surface water for irrigation practices.

7.5.10 Sulphate (SO_4)

Sulphate is predominant anion present in wide range of concentration in natural water. The chief sources of sulphate in ground water are sulphate minerals in sedimentary rocks, oxidation of sulphides from igneous rocks, addition of soil amendments such as gypsum, pyrites, fertilizers and rain water. Analytical results show that the concentration of sulphate in the area ranged from 26 to 786.3 mg/L in pre-monsoon and 112 to 777 mg/L in post-monsoon. WHO, 1993 have prescribed highest desirable limits of 200 mg/L and maximum permissible limit of 400 mg/L for sulphate in drinking water. In most of the water samples, sulphate contents are within the permissible limit except the samples collected from Janalpur, Grdhnur and Rajpur Khurd where the concentration of Sulphate is 786.3 mg/L, 532.5 mg/L and 570 mg/L respectively.

Sulphate at higher concentration can have laxative effect (WHO, 1993). Sulphate ions when associated with high concentrations of magnesium and sodium ions act as laxative and may cause gastric disorders.

7.5.11 Bicarbonate (HCO_3):

The main sources of bicarbonate in ground water include carbondioxide in the soil, leaching from carbonaceous rock, carbondioxide in the atmosphere and carbon dioxide released due to bacterial oxidation of organic matter. The range of bicarbonate concentration in the area is from 112 to 1212 mg/L in and 112 to 1106 mg/L in post-monsoon with an average of 323.8 and 297.61 mg/L respectivly. The maximum concentration is observed in the Janalpur.

7.5.12 Carbonate (CO_3):

Carbonate concentration in the area ranged from 22 to 256 mg/L in pre-monsoon with an average 75.61 mg/l and post-monsoon 18-240 mg/l with an average of 68.26 mg/L. The highest concentration of carbonate (256 mg/L) has recorded at Dankur.

7.5.13 Nitrate NO_3:

Nitrate contamination, often associated with agricultural activities. The most common contaminant identified in ground water is dissolved nitrogen in the form of nitrate. The main sources of nitrate in ground water are industrial wastes, sewage and animal wastes. The concentration of nitrate varied from 11 to 72 mg/L in pre-monsoon and 8 to 75 mg/L in post-monsoon with an average of 32.56 and 29.66 mg/l respectively. In study area the Nitrate contents are within the permissible limit of 50 mg/L

(WHO, 1993). Nitrate content in drinking water is considered important for its adverse health effect. Higher contents of nitrate in drinking water may cause methemoglobinemia in infants. Nitrate can be reduced to nitrite and absorbed into the blood oxidizing the iron of hemoglobin.

7.6 CHEMISTRY OF TRACE METALS

For every metal which man make use of the modern technological society is a potential source of pollution of the biosphere. The multiplicity of the industrial process give rise to a continuously changing pattern of distribution for each element in the biosphere creating in turn their own characteristic ecological consequences. Heavy metals are those having density more than five times higher than that of water. They are usually found in trace amount in natural water. The concentration of trace elements increase in water due to addition of industrial waste and sewage etc. Some of the heavy metals, if present within the permissible limits are essential for the human system, but these can be very harmful if their concentration are high.

Water samples were collected from the study area and analysed for the trace elements like Iron, Manganese, Lead, Copper, Zinc, Cadmium, Chromium (Appendix VII-H). Dispersion of these elements, their sources and various health hazards are discussed below.

7.6.1 Iron (Fe):

Iron is essential element for human, animal and plant growth. Iron is mostly a naturally derived metallic pollutant which owes its origin in water mainly to the sources derived from soil and rock. The major source of iron in water of the study area are mainly industries connected with manufacture of iron or steel and metal plants. Iron concentration in ground water varies from 0.003 to 1.731 mg/L with an average of 0.570 mg/L. The over all distribution of iron is above the permissible limits (0.1 mg/L, WHO, 1993) for drinking water supplies. The higher concentration of iron have been observed at Bulandshahr industrial area, Bahlapur, Makanpur, Near Hindon River, Salarpur Khadar and Bhangel.

Iron is important element for humans and exists in ionic and non-ionic forms. Higher concentration of iron in drinking water imparts bitter sweet, astringent taste and inky flavour.

7.6.2 Manganese (Mn)

The important natural sources of manganese are, the soil of sedimentary and metamorphic rocks. Water pollution of manganese is due to industrial effluents particularly industries manufacturing iron and steel. The concentration of manganese in ground water is usually low due to geo-chemical controls. It is adsorbed on the clays, organic matter, hydrated iron oxides, silicates etc.

Manganese concentration in ground water of the study area is generally within the permissible limits (0.1 mg/L) as prescribed by WHO, 1993. Concentration of manganese is high in Dankaur, Jalapur, Blaspur and Wair The highest value of Mn (0.894 mg/L) has been recorded in Kotderi. The concentration of manganese ranges from 0.004 to 0.894 mg/L with an average of 8.377 mg/L.

Manganese is also an essential element for nutrition of man. It does not appear to have toxicological significance in drinking water at the quantities generally present in natural waters.

7.6.3 Lead (Pb)

Main sources of lead pollution are the effluent of industries such as paints, storage batteries, printing and dyeing, impurities in fertilizers and insecticides. Lead salts are used as anti-knocking compounds in fuel for gasoline.

In the study area lead concentration in ground water are generally high with an average value of 0.155 mg/L. The maximum permissible limit of 0.01 mg/L as reported by WHO, 1993. Maximum concentration has been observed in Dankaur, Wair, Sikandrabad and Rajpur.

The high concentration can have harmful effect on human health. It has adverse effect on the central nervous system, blood cell, kidney and may cause brain damage. As a result of ingestion of lead, there may be loss of appetite, fatigue, irritation, headache and vomiting.

7.6.4 Copper (Cu)

Copper is an essential trace element for human body. Natural source of copper (weathering of sulphide ore) contributes a considerable concentration in ground water. Industrial effluents from plating and electrical units, paints, pumping equipments, textiles and pesticides are the sources of copper.

Copper concentration in ground water ranged between 0.004 mg/L and 1.522 mg/L averaging 0.259 mg/L. The analytical results (Appendix 7.6) shows that the overall concentration of copper in the area is within the permissible limits of WHO, 1993. The daily requirement of copper for an adult is 2.0 mg/L. Copper is involved in hemoglobin synthesis, connective tissue development and normal function of central nervous system. Copper deficiency is linked with anaemia, demineralization of bone etc.

7.6.5 Zinc (Zn)

Zinc is an essential element for plants, animals and man due to its important role in the functioning of various enzymes, protein synthesis and carbohydrate metabolism. It plays an important role in the process of cell division and growth and is present in highest concentration in the liver. The total zinc content of an adult varies from 1.4 to 3 gram.

Zinc in the ground water in the study area may be contributed by industrial effluents like electroplating wastes containing high level of zinc. Zinc concentration in the ground water ranged from 0.004 mg/L to 6.239 mg/L averaging 1.954 mg/L. Overall distribution of zinc in ground water is given in (Appendix VII-F).

Zinc is very significant element for human health and agriculture. Deficiency of zinc may lead to retarded growth, and impaired wound healing.

7.6.6 Cadmium (Cd)

Cadmium is one of the rarer elements in nature and occurs as its sulphide (CdS) and in association with sulphate ore. Cadmium and its compounds are usually present in natural waters in very low concentration.

The concentration of cadmium in the study area ranges from 0.002 mg/L to 3.50 mg/L with an average of 0.168 mg/L. In most of the samples, they are within the permissible limit of WHO, 1993 (0.005 mg/L) but in the areas near the Hindon river and near the industrial area, the concentration of Cadmium exceeded the permissible limit (0.01) of WHO, 1993.

The major source of cadmium in the study area are effluents of industries connected with electroplating, copper and nickel alloys, paints, nickel-cadmium batteries etc. Cadmium is not essential element for human body, high concentration of cadmium causes adverse effect on human body. Renal damage may take place when the concentration is high. Hypertension and cardiovascular diseases has also been associated with cadmium.

7.6.7 Chromium (Cr)

Chromium is one of the most widely distributed heavy metals in the earth crust. It is usually found in two oxidation i.e. Cr^{+3} and Cr^{+6}. Cr^{+3} gets easily oxidized to Cr^{+6} which is more toxic.

Chromium concentrations in ground water ranged from 0.003 to 0.382 mg/L with an average of 0.054 mg/L. In some samples it is below detection limit. WHO (1993) has prescribed 0.05 mg/L of chromium as the maximum permissible limit. Highest concentration of chromium have been observed in Bhopani a industrial area of Noida. Chromium in the area is used in metallurgical industry. It is also used in electroplating, chemical and Dyes industries.

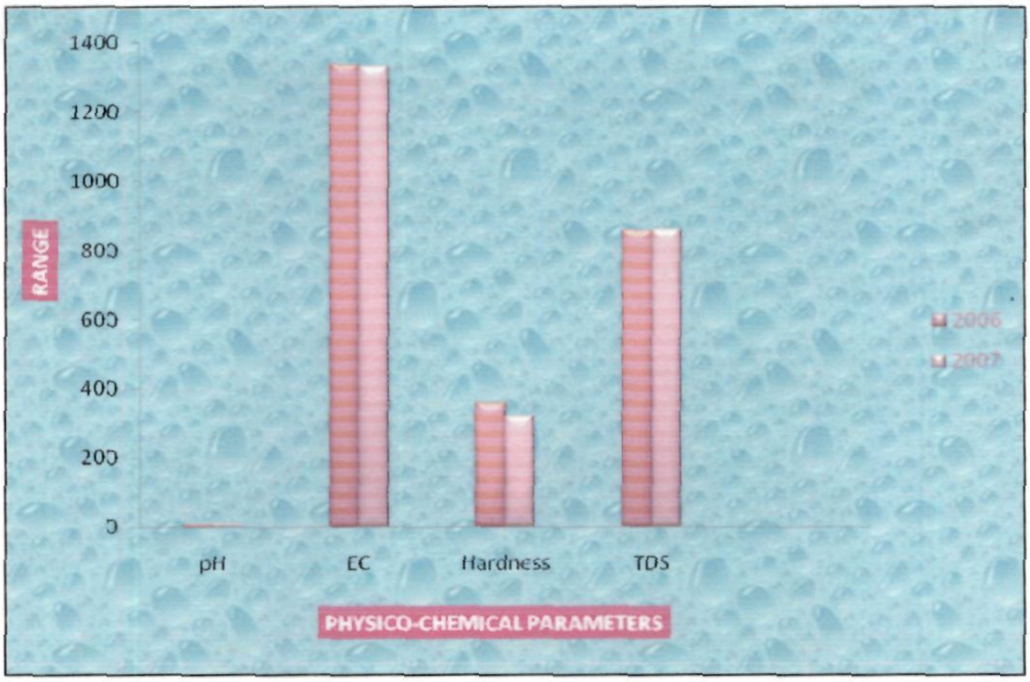
Toxicity of chromium is greatly dependent upon the hardness of water, which works antagonistically with it. The mode of contamination of chromium in water, air and their effect on human being is carcinogenic.

7.7 GRAPHICAL PRESENTATION AND HYDROCHEMICAL FACIES

An important task in ground water investigation is compilation of chemical data in a convenient manner for visual inspection. For this purpose graphic representation are useful for display, comparing analyses for emphasizing similarities and differences. A variety of graphic techniques have been developed for showing the hydrochemical data. In the present study bar graph, Gibbs variation diagram, tri-liner piper diagram have been used for the presentation of the results of chemical analysis. Bar diagram has been prepared for representing the individual average concentration of major ions in 60 different sampling stations (Fig. 7.2-A and 7.2-B).

7.7.1 Trilinear Piper Diagram

The trilinear diagrams are useful for visually plotting the difference in major-ions chemistry in ground water flow system. In order to present water composition in convenient manner by identifiable groups, Back (1961, 1966), and Morgan and Winner (1962) have developed the concept of Hydrochemical facies. Hydrochemical facies are distinct zones that have cation and anion concentrations describable within defined



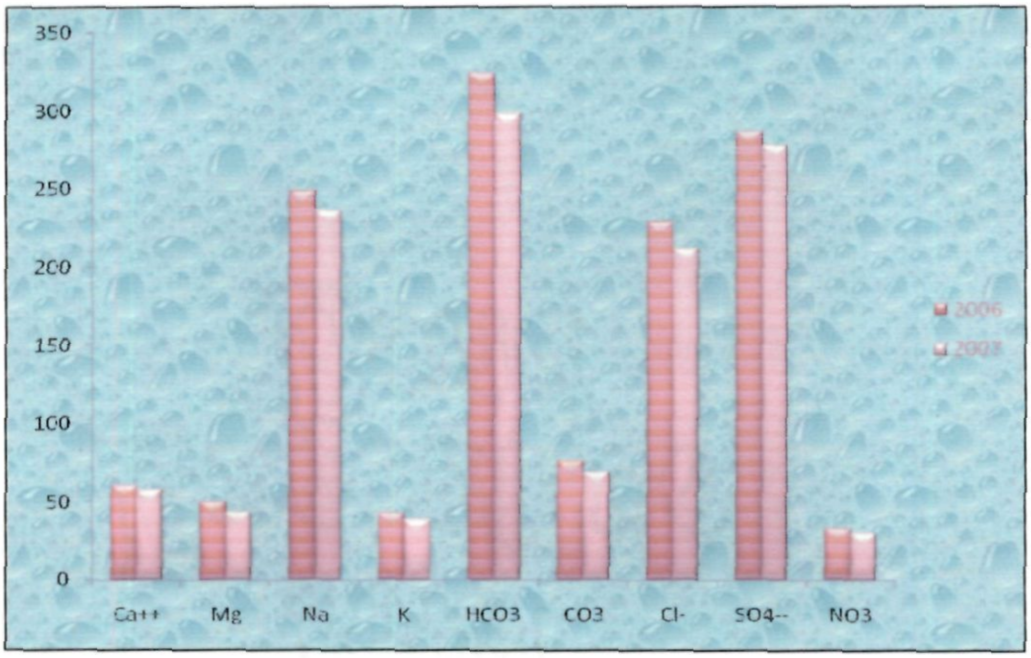
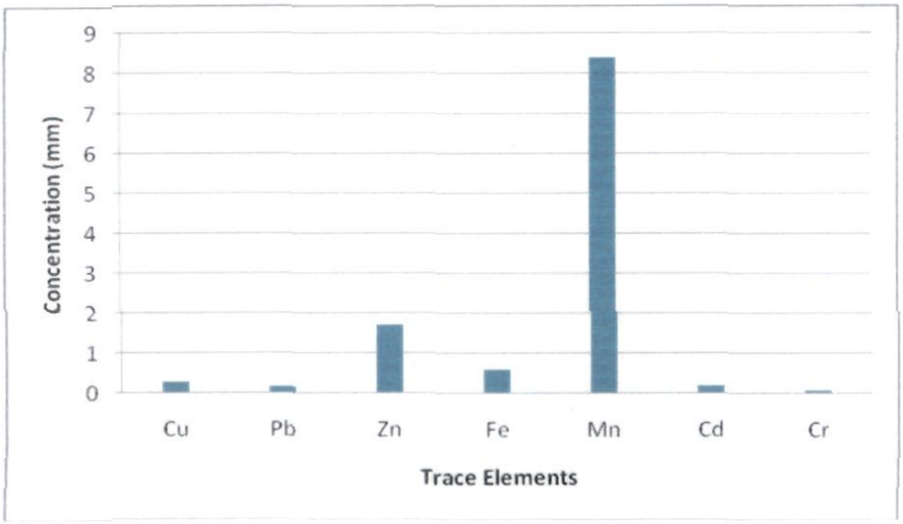
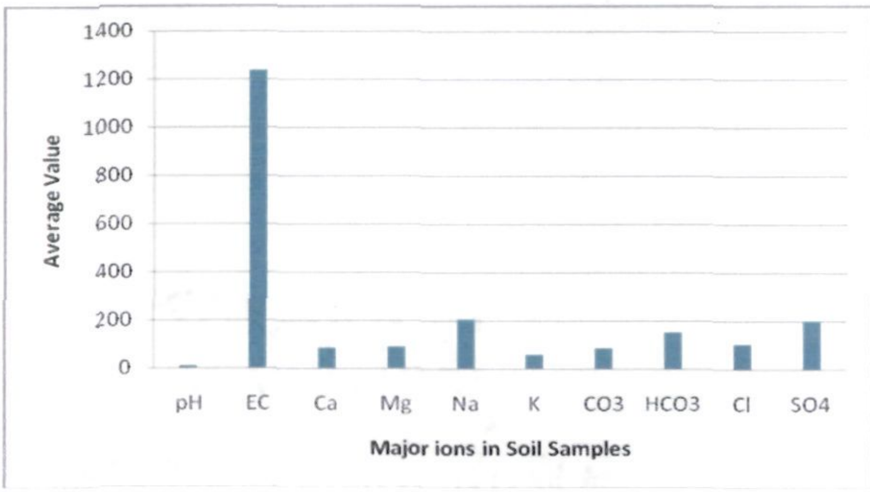


Fig.7.2(A). Graph showing Physico-Chemical parameters and average concentration of major ions.



Average concentration of Trace elements in Groundwater samples



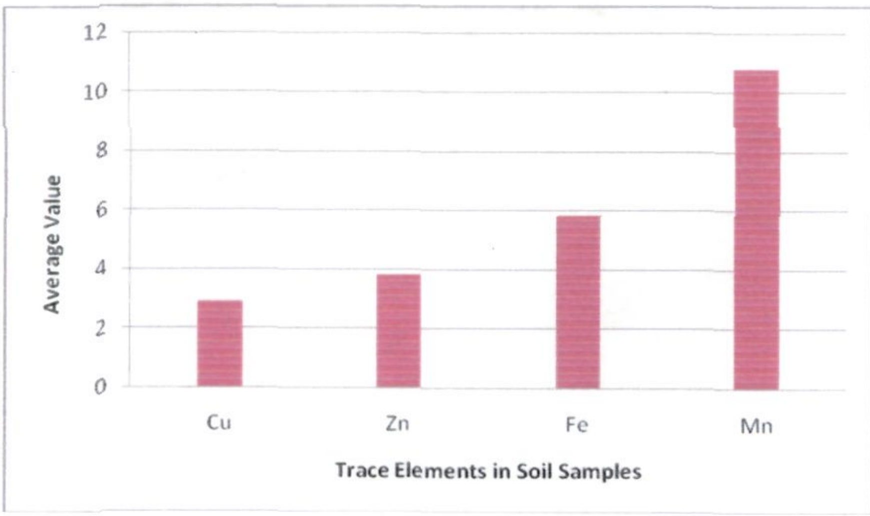


Fig. 7.2 (B).Graph showing average concentration of trace element in groundwater samples and major ions and trace elements in soil samples.

composition categories (Allan and Cherry, 1979). According to Back (1961) the term hydrochemical facies is used to describe the bodies of ground water in an aquifer that differ in their chemical composition. The facies are a function of lithology, solution kinetics and flow pattern of the aquifer (Back, 1966).

The percent values of cations and anions of pre-monsoon and post-monsoon groundwater samples have been plotted on tri-linear diagram (Fig. 7.3 and 7.4). In order to designate hydrochemical facies of the study area Morgan and Winner (1962) and Back (1966). The plotting of analytical results shows that sodium or potassium is the dominant facies among the cations. About 54% of the samples in premonsoon and 88% in post-monsoon samples found to fall in sodium, potassium type facies, only seven samples fall in calcium type facies and the six in pre-monsoon and seven in post-monsoon samples in no dominant type, seven in pre-monsoon falls in magnesium type. Among the anion facies, majority of the samples fall in no dominant type facies followed by sulphate and bicarbonate type facies. Few sample belong to chloride type.

7.7.2 Sodium Adsorption Ratio (SAR) and salinity hazards

Suitability of water for agricultural purposes can better be assessed by Sodium Adsorption Ratio (SAR) because of its direct relation to the adsorption of sodium by soil, as shown by formula:

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

where the concentration of the constituents are expressed in milli equivalent per litre. The quality classification of irrigation water as suggested by U.S. salinity laboratory is given in Appendix 7.1.

Table-7.1: Quality classification of irrigation water (after U.S.S.L., 1954).

Salinity hazards (E.C. in μs/cm)	Alkali hazards (SAR)	Water class
< 250 (C1)	< 10 (S_1)	Excellent
250 – 750 (C_2)	10-18 (S_2)	Good
750 – 2250 (C_3)	18-26 (S_3)	Moderate
> 2250 (C_4)	> 26 (S_4)	Poor

The electrical conductivity and sodium adsorption ratio are plotted on U.S. salinity diagram which gives direct indication of the salinity and alkali hazard. The salinity hazard increase as the soils become finer grained and aridity increase resulting in the concentration of salt in the soil that may require periodical leaching. Excessive sodium content in water renders it unsuitable for soils containing exchangeable calcium and magnesium. Fig (Fig. 7.5 and 7.6) shows that most of the samples of pre- and post-monsoon belongs to the categories of C_3S_1 and C_3S_2 which falls within the zone of moderate to good water quality class. The SAR values

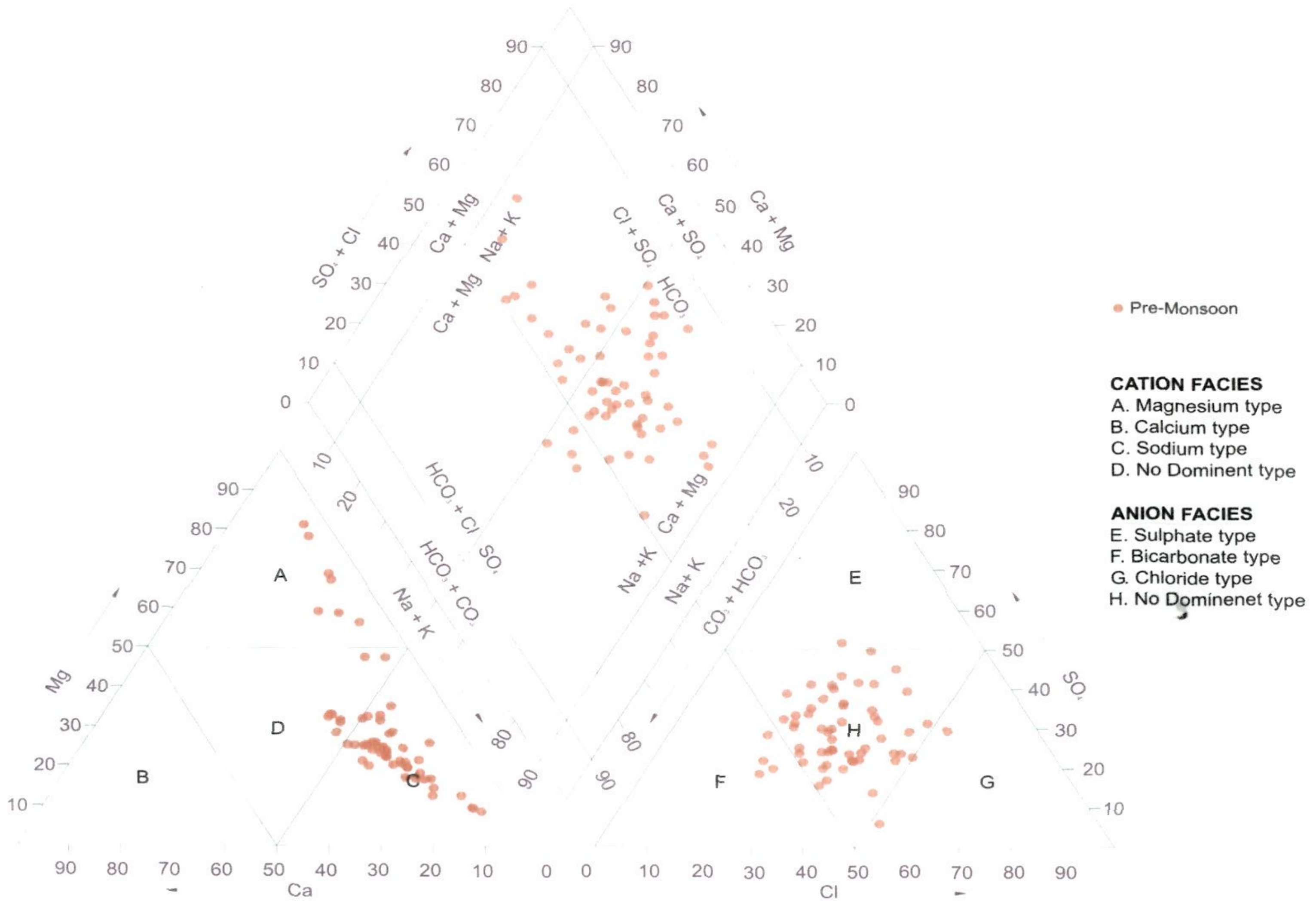


Fig. 7.3: Piper's Trilinear diagram showing chemical character of Groundwater during Premonsoon 2006.

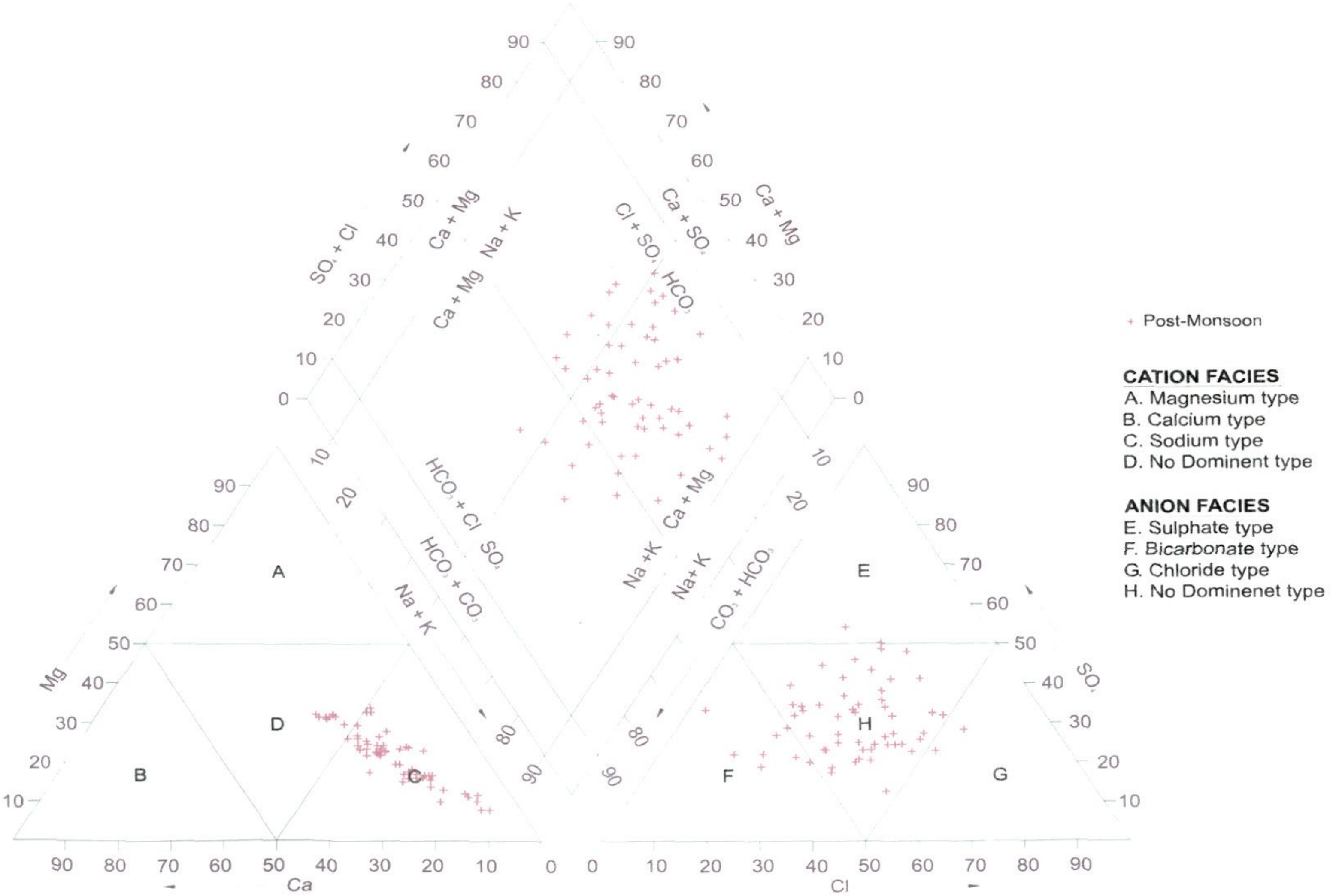


Fig.7.4 : Piper's Trilinear diagram showing chemical character of Groundwater during Postmonsoon 2007.

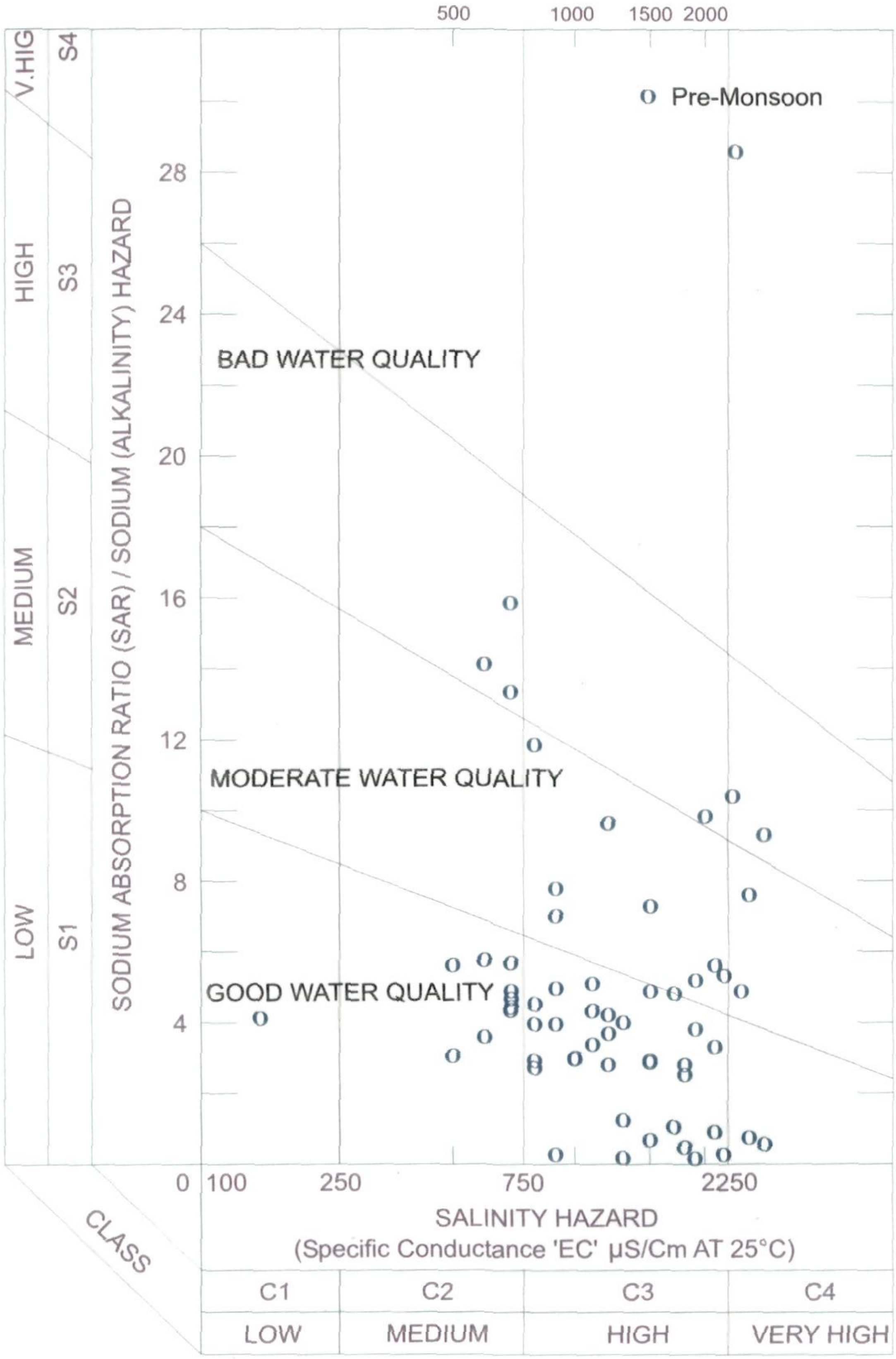


Fig. 7.5: Plot of SAR values against EC values of Premonsoon 2006.

(US Salinity diagram, after Richard 1954)

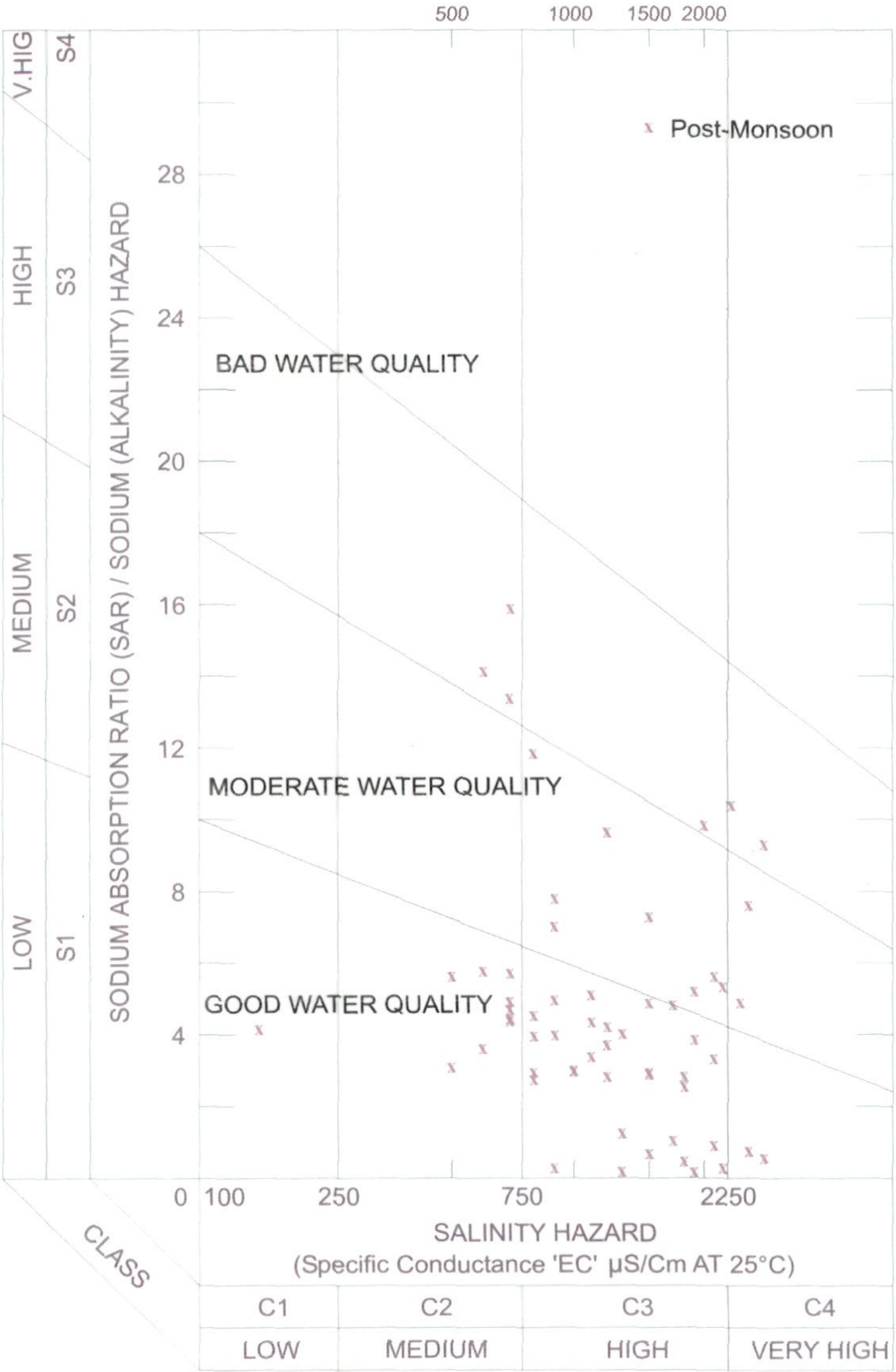


Fig. 7.6: Plot of SAR values against EC values of Postmonsoon 2007.

(US Salinity diagram, after Richard 1954)

in 55 out of 60 samples were less than 10 and EC values is about 32% of the water samples are greater than 1500 μS/cm, hereby indicating low alkali hazard and high salinity hazard.

7.7.3 Water Quality Standards for Irrigation

Utilization of ground water for irrigational purpose depends on many factors such as texture and composition of soil, type of crop, climate, irrigational practices and finally chemical quality of ground water, with regard to the quality of water for irrigation, the major parameters of concern are salinity, dissolved solids, conductivity, toxic trace elements and herbicides. Besides, the presence of sodium is also an important parameter, the excess quantity of which can deteriorated the soil. High value of sodium may also damage the sensitive crops because of sodium phototoxicity – Wilcox (1955) proposed a classification based on the Electrical conductivity, sodium percent and iron concentration for irrigation water. The sodium % is calculated by the following formula given by Todd, 1980.

$$\% \text{Na} = \frac{(\text{Na} + \text{K})\ 100}{(\text{Ca} + \text{Mg} + \text{Na} + \text{K})}$$

The value of individual constituents are taken in epm. Sodium ions have a tendency to be adsorbed by soil collides. Increase of sodium ion contents in water beyond 50% replaces the ions like Ca + Mg in soil by base exchange. Percent sodium upto 50% is acceptable for irrigational use above which alkalization steadily increases. This will support little or no plant growth. The following classification based on percentage sodium and electrical conductivity of water for irrigation has been given by the Wilcox, 1955.

Table 7.2: Quality classification of water for irrigation (Wilcox, 1955)

(E.C. in μs/cm)	Na %	Water class
< 250	< 20	Excellent
250 – 750	20 - 40	Good
750 – 2000	40 - 60	Permissible
2000 – 3000	60 – 80	Doubtful
> 3000	> 80	Unsuitable

The values of percent sodium against EC are compared and plotted on Wilcox diagram (Fig. 7.7 and 7.8). The Fig. reveals that there is variation in the water quality of the area. 16% in pre and 17% in post-monsoon of the water samples fall in excellent to good. About 33% in pre and 36% in post-monsoon belongs to permissible to doubtful and 20% of the samples falls in the unsuitable class.

7.7.4 Gibbs variation Diagram

Gibbs (1970) variation diagram has been used to study the mechanism controlling water chemistry. It is observed that the water chemistry of the area occupies the field of rock dominance in (Fig. 7.9

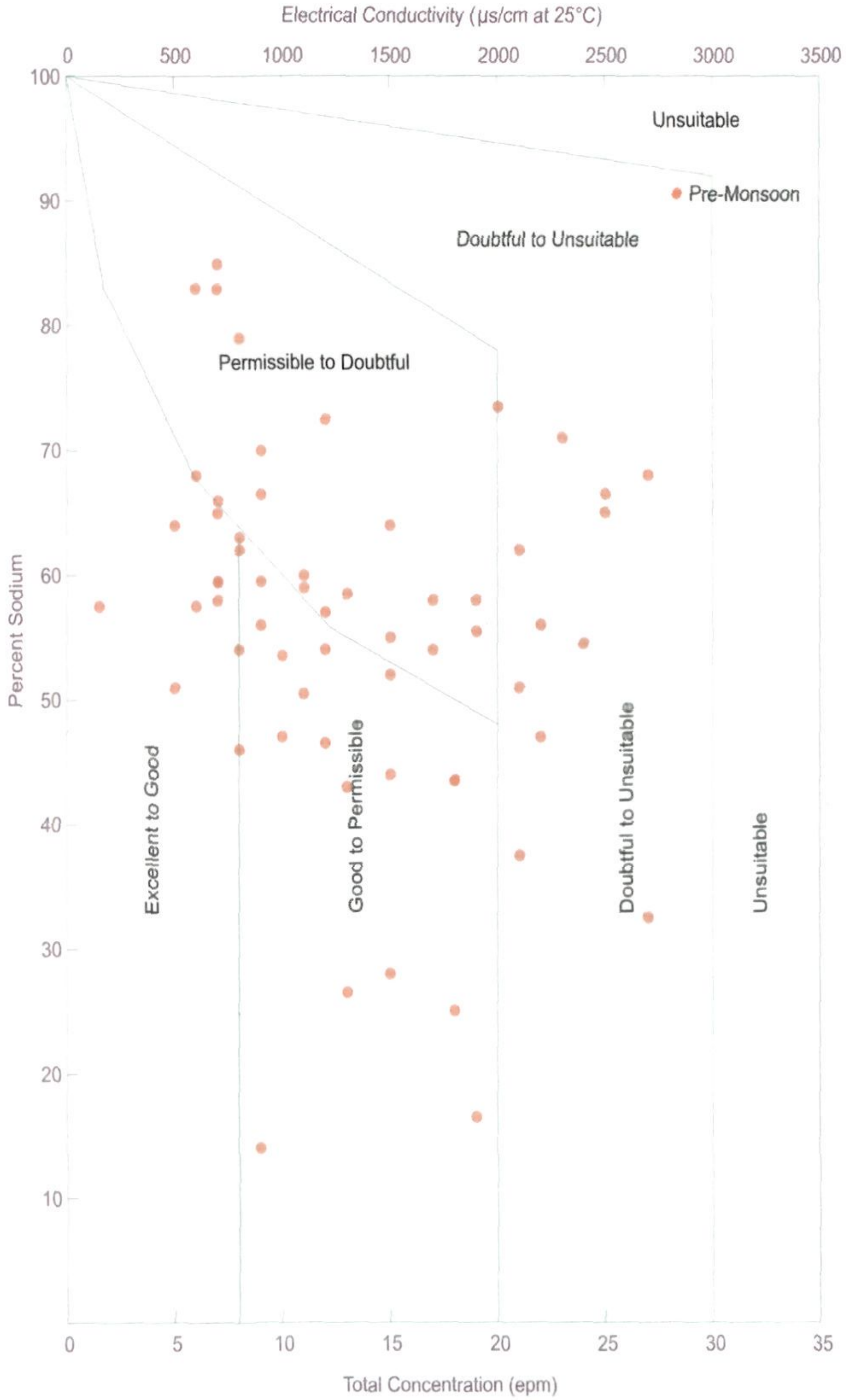


Fig.7.7 : Plot of Sodium percent vs. Electrical Conductivity (after Wilcox, 1955) Premonsoon 2006.

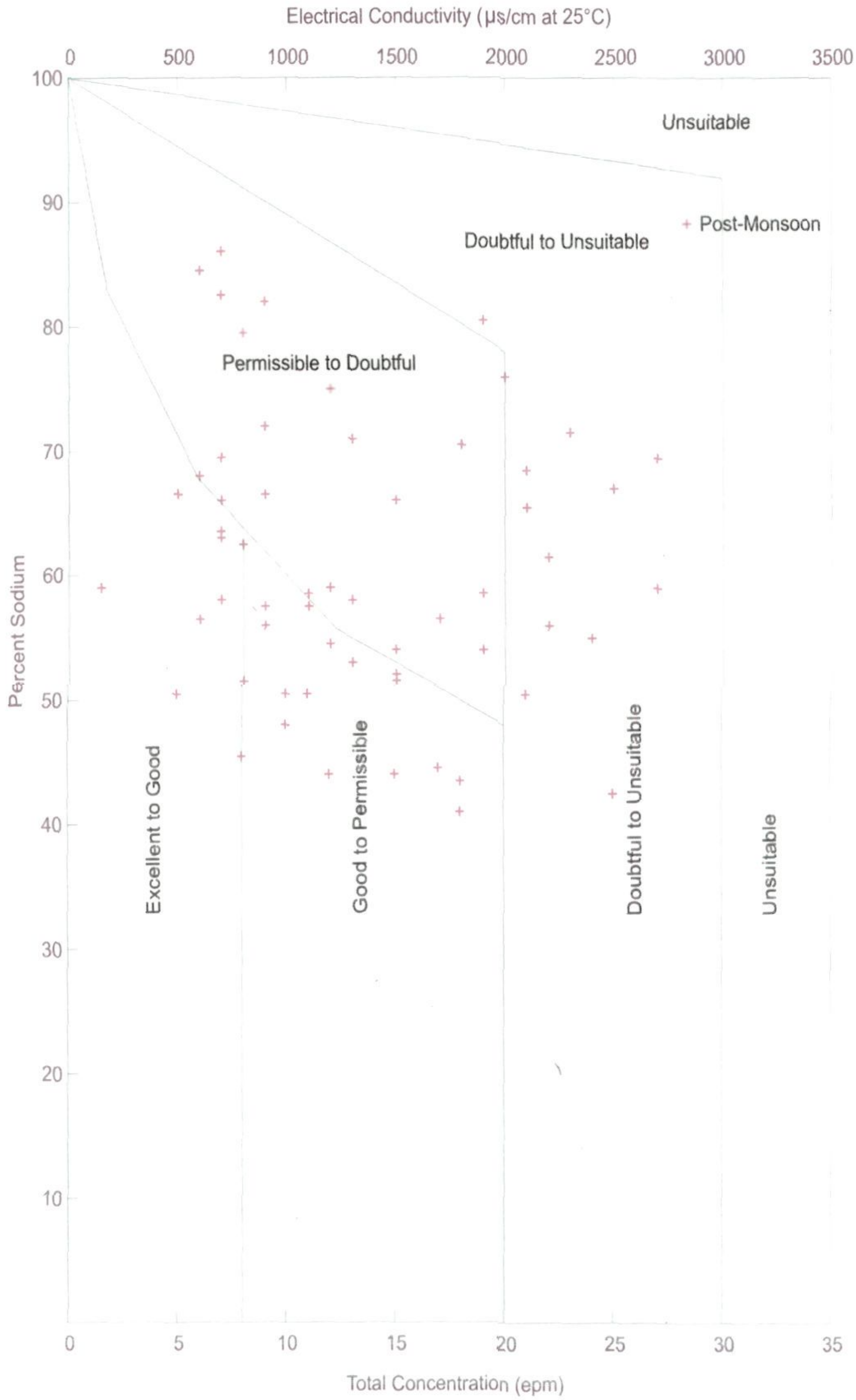


Fig. 7.8: Plot of Sodium percent vs. Electrical Conductivity (after Wilcox, 1955) Postmonsoon 2007.

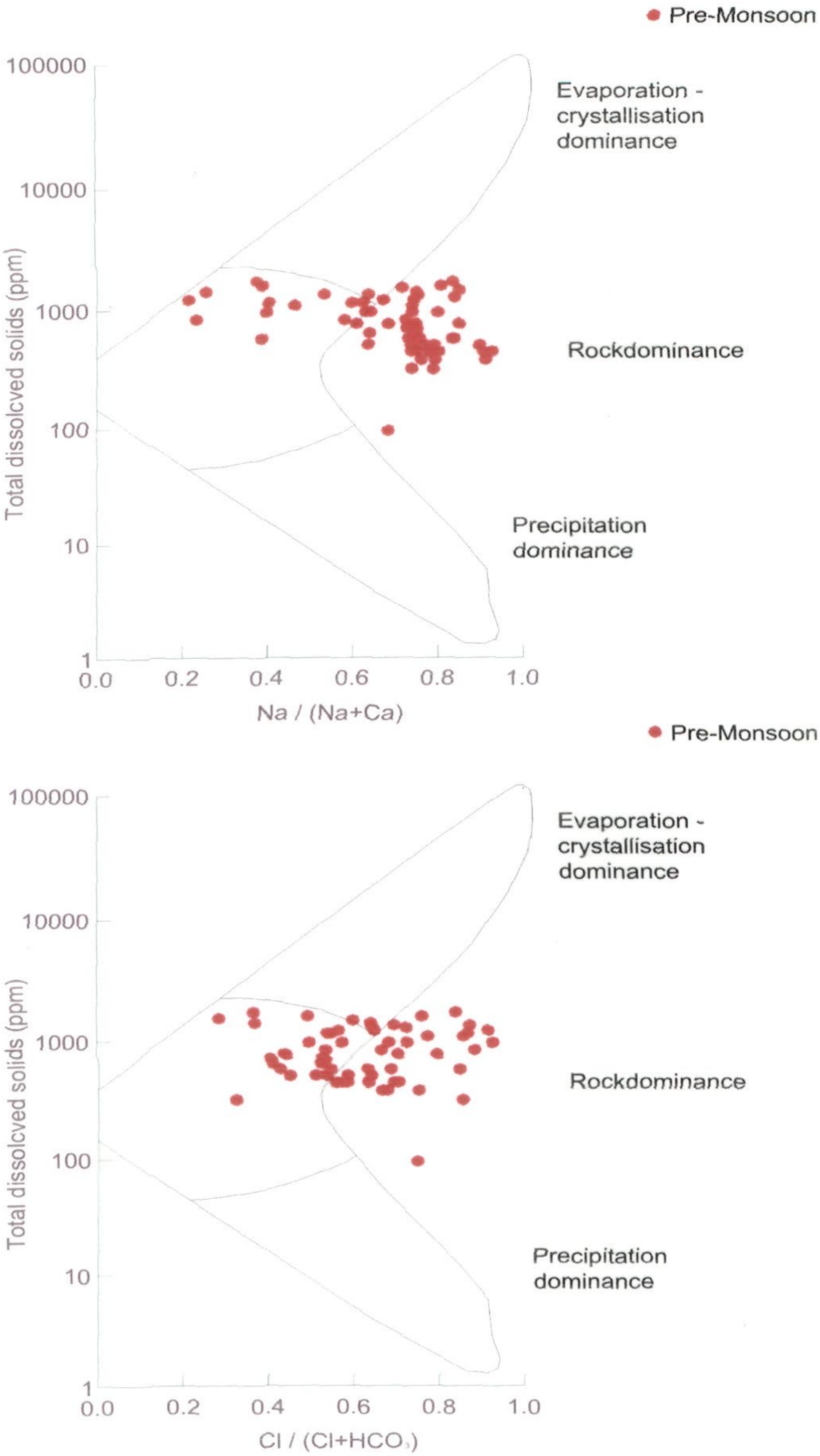
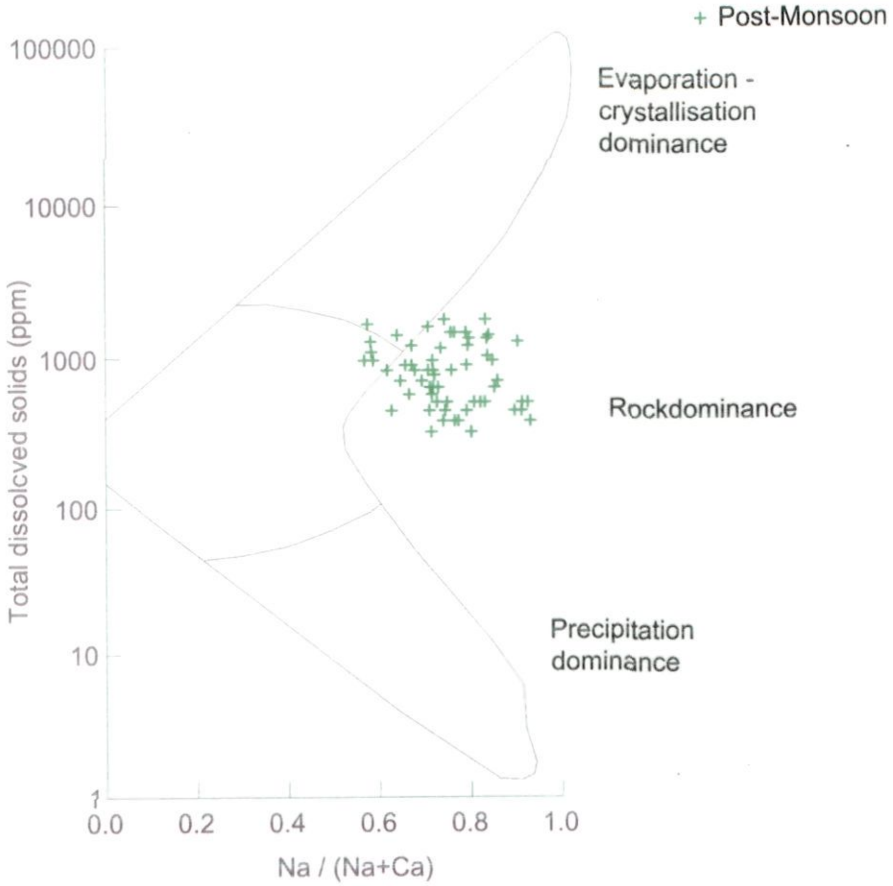


Fig. 7.9: Chemical data for groundwater plotted in accordance with the scheme of Gibbs (1970) Premonsoon 2006.



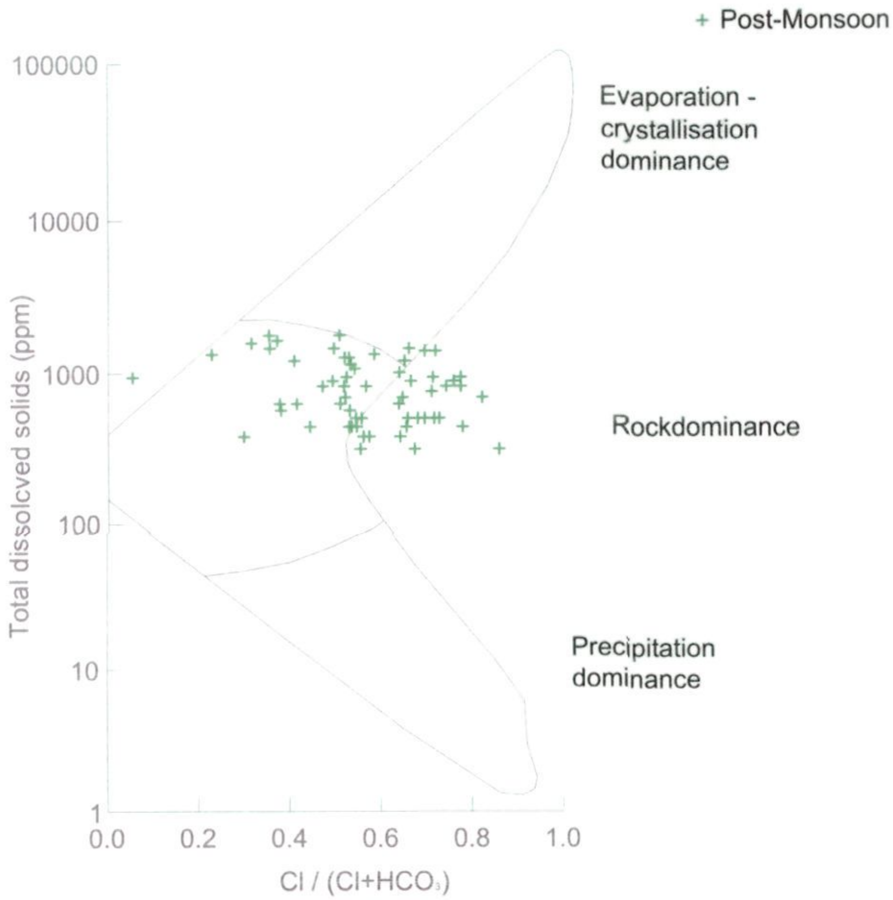


Fig. 7.10: Chemical data for groundwater plotted in accordance with the scheme of Gibbs (1970) Postmonsoon 2007

and 7.10). The mechanism controlling water chemistry and functional source of dissolved ion can be assessed by plotting hydrochemical data according to the variation in the ratios of Na^+: ($Na^+ + Ca^{2+}$) and Cl: ($Cl^- + HCO_3^-$) as functions of TDS. The plot of data on the diagram suggest that chemical weathering of rock forming minerals and evaporation are the dominant factor controlling groundwater chemistry in the area.

7.8 CORRELATION MATRIX AMONG THE VARIOUS WATER QUALITY PARAMETERS

Water is the most abundant essential component and is a universal solvent. Because of unabated increase in the deterioration of surface water quality, ground water is perhaps the most important component of the total water system for human consumption. Correlation among water quality parameters greatly facilitate the task of rapid monitoring of water quality (Tiwari and Ali, 1998). Jain and Sharma (1997) have calculated correlation in order to ascertain the relationship among water quality parameters of ground water.

In the present study correlation among various chemical variables in pre-monsoon and post-monsoon have been calculated (Table 7.3 and 7.4) respectively. The highest positive correlation (0.999) in pre and (0.990) in postmonsoon found between electrical conductivity and total dissolved solids which indicates that the electrical conductivity in the

Table 7.3: Inter Elemental Correlation Matrix of Pre-monsoon 2006

	pH	EC	TDS	Hardness	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
EC	0.843	1											
TDS	0.843	0.999	1										
Hardness	0.823	0.791	0.791	1									
Ca	0.865	0.767	0.767	0.919	1								
Mg	0.697	0.721	0.721	0.950	0.752	1							
Na	0.154	0.210	0.210	0.094	0.095	0.083	1						
K	-0.176	-0.111	0.111	-0.035	0.012	-0.069	-0.012	1					
Cl	0.221	0.138	0.138	0.118	0.231	0.016	0.284	0.236	1				
CO_3	-0.009	0.074	0.074	-0.074	-0.160	0.001	-0.013	-0.206	-0.089	1			
HCO_3	0.512	0.543	0.543	0.420	0.374	0.408	0.197	-0.176	0.172	0.319	1		
SO_4	0.233	0.334	0.334	0.163	0.221	0.098	0.128	-0.063	0.297	0.128	0.458	1	
NO_3	0.207	0.356	0.356	0.303	0.195	0.353	0.157	0.032	0.085	0.039	0.169	0.200	1

Table 7.4 Inter Elemental Correlation Matrix of Post-monsoon 2007

	PH	EC	TDS	Hardness	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
EC	0.767	1											
TDS	0.759	0.990	1										
Hardness	0.753	0.734	0.725	1									
Ca	0.814	0.740	0.729	0.913	1								
Mg	0.588	0.620	0.615	0.930	0.700	1							
Na	0.157	0.184	0.171	0.050	0.106	-0.007	1						
K	-0.158	-0.081	-0.055	0.035	0.041	0.024	0.026	1					
Cl	0.186	0.133	0.134	0.059	0.194	-0.071	0.292	0.155	1				
CO_3	-0.002	0.085	0.090	-0.107	-0.193	-0.013	-0.035	-0.247	-0.041	1			
HCO_3	0.495	0.540	0.525	0.452	0.395	0.437	0.186	-0.182	0.118	0.289	1		
SO_4	0.208	0.390	0.378	0.166	0.187	0.123	0.108	-0.012	0.258	0.110	0.434	1	
NO_3	0.185	0.327	0.308	0.220	0.148	0.252	0.156	0.100	0.136	0.042	0.207	0.234	1

groundwater of the area is due to total dissolved solids. The high correlation of electrical conductivity, total dissolved solids, sodium and potassium with magnesium sodium, potassium and chloride also observed. This indicates that the water of the area contains chloride salt of sodium and potassium. A positive high correlation between sodium and chloride is an indicative of sodium chloride in the waters. The highest negative correlations were observed between pH, Potassium (-0.176) and between Ca and CO_3 (-0.160) in pre-monsoon. The high correlation also observed between the hardness with calcium.

7.9 MAJOR IONS AND TRACE ELEMENTS IN SOIL SAMPLES

Soil samples have been collected from the different location of the study area. Twenty five samples were analysed for major and trace elements. The concentration of major ions in soil samples and Trace elements in Appendix VII-G and VII-H.

The pH value in soil sample ranges between 7.2 to 8.3 and E.C. ranges 600 to 2000 µs/cm.. The concentration of Ca, Mg, Na, K, Cl, HCO_3, CO_3 and SO_4 ranges from 40.6 to 143.3 mg/L, 35.8 to 695.2 mg/L, 98.0 to 391.6 mg/L, 18 to 90.3 mg/L, 98 to 235 mg/L, 18.6 to 575 mg/L, 33.3 to 16 mg/L, 32.3 to 485 mg/L.

The concentration of heavy metals in the soil samples given in Appendix 7.8 are comparatively higher than the water. Four trace elements have been analysed i.e. Zn, Fe, Mn, Cu, zinc concentration ranged between 0.261 t o 10.2 mg/L averaging 3.82 mg/L. The maximum concentration has been recorded in the soil samples collected from Lal Kuan industrial area and Tusiana where as minimum value is observed at Makhanpur. The concentration of iron ranges from 1.33 to 17.23 mg/L averaging 5.82 mg/L. Highest concentration of iron was observed near the Chora Sadatpur. Manganese concentration varies from 2.05 to 24.14 mg/L with an average of 10.77 mg/L. The higher concentration of Mn recorded from Tilapat and minimum at Pali. Copper concentration ranges from 0.1 mg/L to 10.4 mg/L with an average of 2.88 mg/L.

7.10 Hydrochemical characteristic of Groundwater

A number of x-y plots were prepared for deciphering various chemical alteration trends of groundwaters and identifying the processes involved in the acquisition of distinct chemical characteristics.

Alkalis are distinctly far more abundant than Ca^{++} and Mg^{++} in both the sets of samples (Fig.7.11). The HCO_3^- versus $Cl^-+SO_4^-$ plot (Fig.7.12) tends to classify the groundwater in the study area in two groups, i.e. (i) $HCO_3^- > Cl^-+SO_4^-$ and (ii) $Cl^-+SO_4^- < HCO_3^-$. Both the plots further

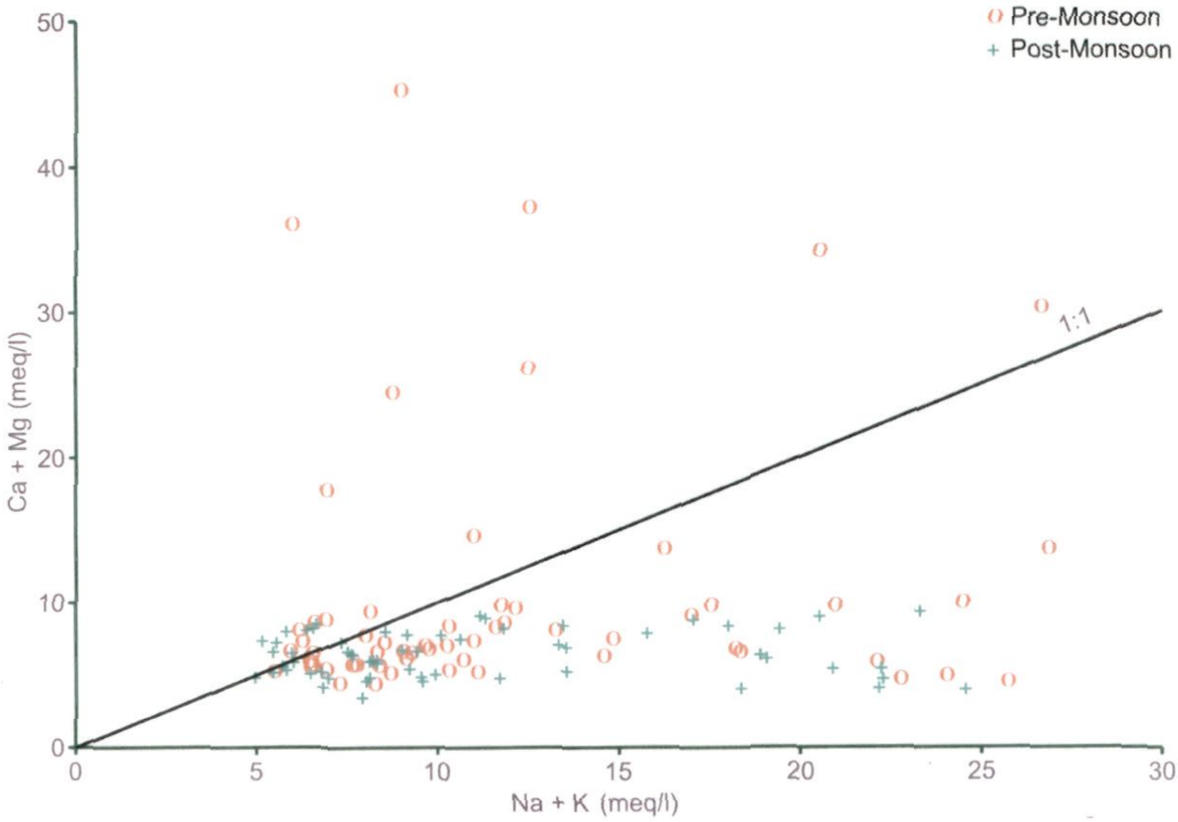


Fig. 7.11: Relative abundance of alkali's over Ca+Mg.

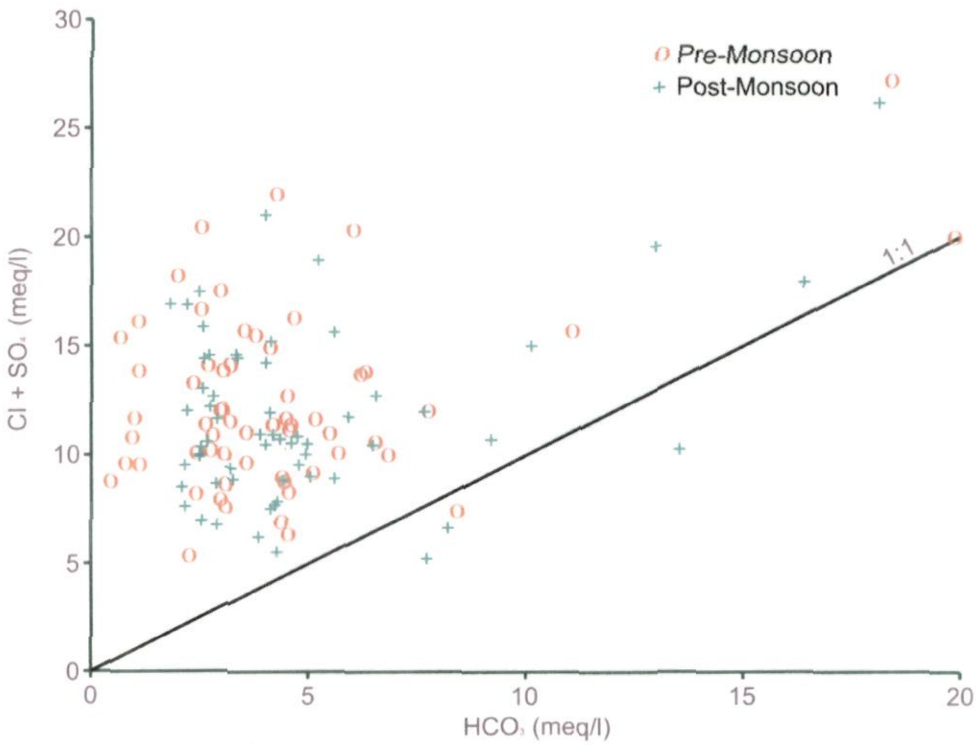


Fig. 7.12: Relative abundance of HCO $_3$ and Cl+SO$_4$.

indicate that chemical differences between pre and post monsoon sets of samples are relatively trivial.

The natural tendency between cations and anions to form ionic complexes has been tested Na^{+}+K^{+} and Cl^{-} (Fig.7.13) and Ca^{++}+Mg^{++} and HCO_3^{-} (Fig.7.14). Without depicting any noteworthy change in concentration levels recorded in pre and post monsoon samples, the majority of the samples plot below 1:1 line on alkali versus Cl^{-} plot implying surplus Na^{+} ion over and above those used up in Na-Cl bonding. Relative abundance of Na^{+} ions is also implied in molar Cl^{-}/Na^{+} ratios averaging around 0.25. Na behaves like a conservative elements as it is not used up in biological processes and also as an non-conservative elements as it gets fixed in clay mineral formation by ion exchanges (Subramanian and Sexena 1983).

The Ca^{++}+Mg^{++} and HCO_3^{-} plot (Fig.7.14) depict a moderately good correlation for about 40% of all pre and post monsoon samples. Nevertheless, there is considerable scatter in the plot due to relative preponderance of HCO_3^{-}, and this when viewed in the light of relative abundance of alkali over Ca^{++} and Mg^{++} (Fig.7.11) and evidence for surplus Na^{+} ions (Fig.7.13) implies that in a considerable number of samples Na-HCO_3 may be the most dominant ionic complex. This unique chemistry acquired is because of ion-exchange reactions. The reactions

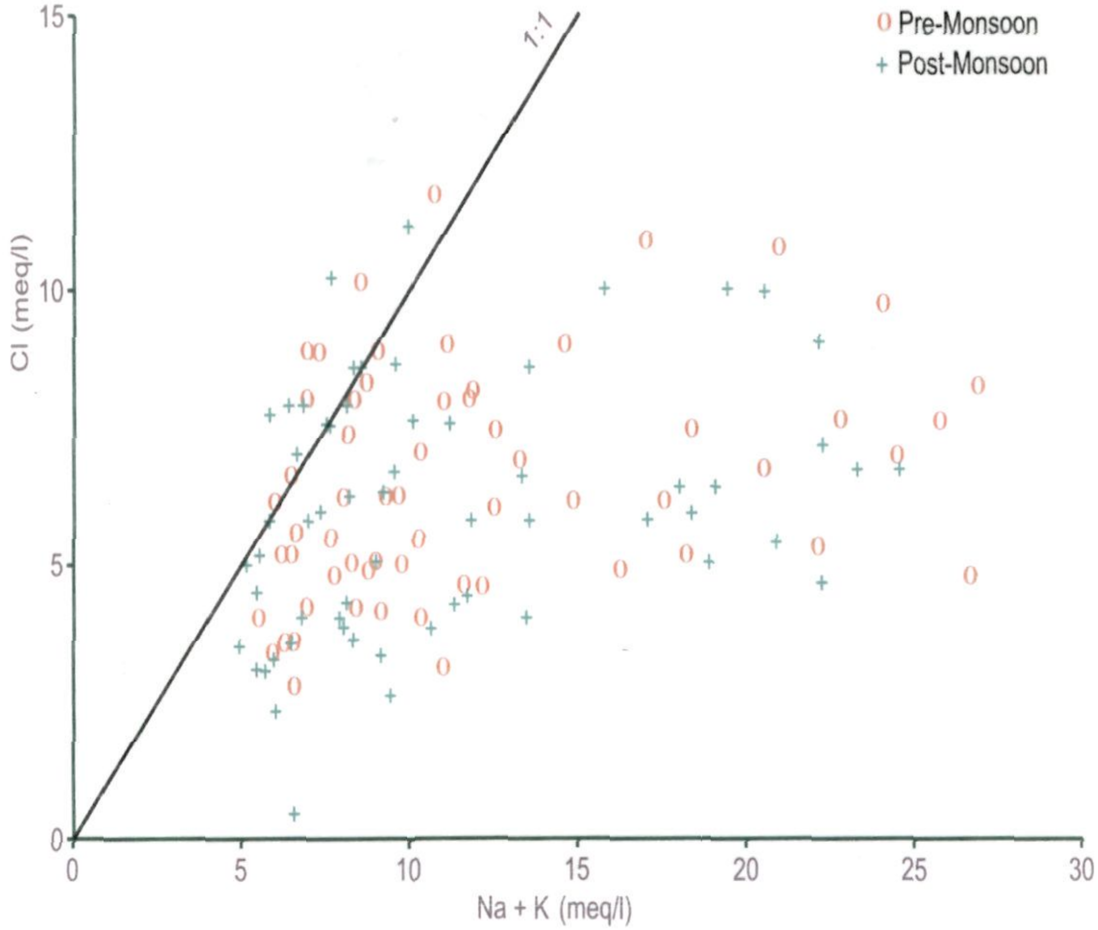


Fig. 7.13 : Showing bonding affinity between alkali's and Cl.

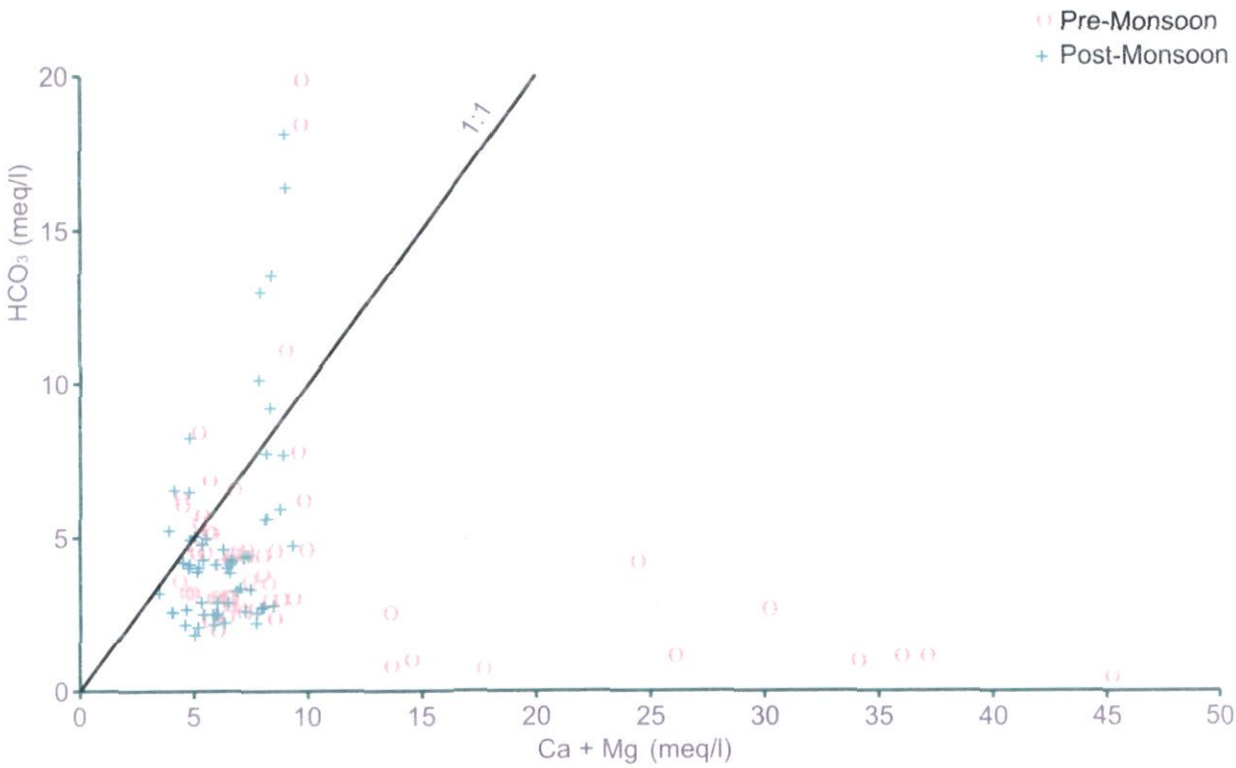


Fig. 7.14 : Bonding affinity between Ca+Mg and HCO

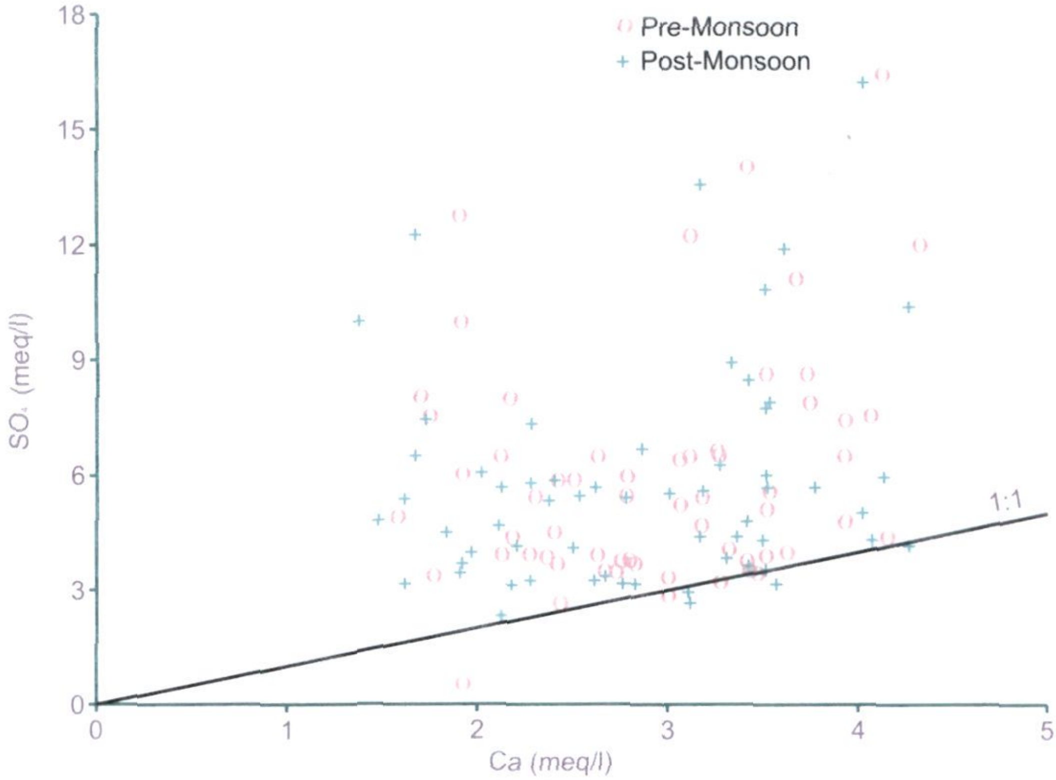


Fig. 7.15 : Bonding affinity between Ca and SO

that oxidize organic matter generate CO_2 as a product. This CO_2 is redistributed among H_2CO_3, HCO_3^- and CO_3^-. In aquifers where Ca^{2+}, and Mg^{2+} are exchanged in to clay minerals for Na^+, the possibility exist for carbonate dissolution and even higher HCO_3^- concentration. With CO_2 generated by redox reaction (in the upper humic zone of aeration), ion exchange and carbonate dissolution, the water will evolve to a Na-HCO_3 type (Domenico 1997).

The ions exchange reactions are favoured by clay layers. The Na-SO_4-HCO_3 type facies is more evolved species of ion exchange reaction. The presence of calc-concretion (kankar) could favour the weathering processes.

One of the characteristic features of the groundwater from the study area is its relative enrichment in SO^{--}_4 . Processes such as oxidation of sulphides and dissolution of gypsum (Valdiya 1980 and Chakrapani 2005) are not inferred to play a significant role in acquisition of sulphate ion by the groundwater of the area when the geological setup of the area is taken into consideration. That dissolution of gypsum (either naturally occurring as gypsite in some parts of Indo-gangetic plains or that used as a fertilizer) has almost no role to play in determining the concentration in groundwaters of the study area is also borne out by Ca-SO_4 plot (Fig.7.15), which depicts overwhelming abundance of SO^{--}_4 compared to that of Ca^{++}. The dissolution of kankar by sulfuric acid, produced through SO_x emission dissolved in rain from industrial emissions and effluents (Kumar et al 2006).

SUMMARY
&
CONCLUSION

SUMMARY AND CONCLUSION

Environment is an all encompassing term embracing atmosphere, hydrosphere and lithosphere. The biotic component of environment is totally dependent for its existence on these three cornerstones. The lithosphere comprises rocks in all its manifestation including micro to global scale geological structures and soils which are basically derived from the rocks. The geological processes operating over many millennia have shaped the landscape (geography and geomorphology) all over the world and in which all terrestrial living being reside. The hydrosphere encompasses surface water of all description including the polar caps, glaciers, oceans, surface and groundwater, which constitutes the habitate of all aquatic life forms.

The environment is the sum of all external influences and conditions affecting life and development of organism. The intensity of man's activities, diversity and magnitude of different types of waters introduced into the environment are increasing at an alarming rate. Environmental pollution is generally referred as the unfavorable alteration of our surroundings and occurs mainly because of the action of the men. Environmental pollution take place through changes in energy patterns, radiation levels, physical and chemical constitutions and abundance of organism.

Water is among the most essential requisites that nature provides to sustain life for plants, animals and humans. The total quantity of fresh water on earth could satisfy all needs of the human population, where, it evenly distributed and accessible (Bobba et al. 1977). The availability of water resources has been the essence for establishment and growth of human population. This developmental activity of human being with time led to establishment of industries around the water resources which in turn attracted more population, as a result of this cycle.

The rapid pace of urbanization, industrialization as well as agricultural activities has made environmental pollution a growing concern globally. The most important cause of groundwater pollution is unplanned urban development without adequate attention to sewage and waste disposal. Indiscriminate disposal of both hazardous and non-hazardous industrial water has further aggravated problems associated with water resource for drinking and irrigation. The deterioration of groundwater quality due to industrial effluents and municipal wastes in the study area is a live example. The waste generated by anthropogenic activities has not only polluted the environment as a whole but had a particular detrimental effect on the quality of aquato-envision too.

The study area is the most industrialized districts adjoining National Capital Territory of Delhi located on the fringe of the Yamuna river. There are thousands of industries manufacturing electrical goods, general engineering equipments, tractors, transport and agricultural implements, chemical industries, Electro plating, leather, rubber, tyre, paper, plastic and other products. Apart from industrial growth there has been remarkable development in the field of agriculture. This development in industrial and agricultural sector has resulted in the over exploitation of groundwater and deterioration of both surface and sub-surface water quality in the research area.

The study area falling under the National Capital Region is densely inhabited belt of the India. The anthropogenic processes including the rapid urbanization (settlement of colonies) and industrialization (growth of major and minor industries) have been taken place in an around study area. Besides this, causes of floods and their impact on environment, water logging problems, mining activities and degradation of water quality due to effluent discharge form various industries in the natural water system and landfills, are some of the geo-environmental problems associated to the study area. The interference with the geo-environmental system has resulted in a series of imbalance leading to severe geo-environmental degradation.

The technological advancement in the drilling activities, better development of pump sets, reduction in cost and availability of energy have led to a massive groundwater development. This has resulted in the decline of water levels at many places. Water logging condition also occurs in the areas close to canal command due to induced seepage.

Physiographically the area has been divided into three distinct geomorphic units i.e. **rocky surface, higher alluvial surface** *and* ***flood* plains**. The **rocky surface** occupied by peneplained ridges of Aravalli mountain chain. These ridges are flat-topped and do not show appreciable differences and hence bears the look of plateau. The rocky surface has an over all slope towards north and east on the eastern side, the ridge slopes towards the Yamuna river with a gradient of about 3.3 m/km. On the southern side, it terminates abruptly plunging beneath the alluvium while towards north it gradually slopes beneath the alluvium. ***Higher Alluvial surface*** has a general elevation of 224m above mean sea level in the northern part and slopes down southerly to an average elevation of 213m to 210 m. in the central part around Ghaziabad and finally an average altitude of 196-199 m in the southern part of Ballabgarh. Higher alluvial surface in the area is drained by the Yamuna river. The lower plains are characterized by extensive agricultural activities and spatial disposition of wells and tubewells.

The **flood plains** are characterized by heterogeneity of land forms. There is a capping of greyish fine sand or slight greyish to greyish brown silt clay, often intercalated with calcareous concretions of varying sizes. The present day flood plains extend upto 2.5 km along either banks of the Yamuna. However, they are well developed on the eastern bank with an average width of 2.5 km but upto 4 km at places The palaeo- channels of Yamuna river characterized by the 8-15 km wide river valley as compared to the present day 3-10 km wide floods plain. At flood plains at least three major abandoned channels, two of these associated with levees and sand bars, occupy the central part in north-south direction. Some parts of flood plain around Chaprauli, Tilpat, Dadsia areas. show close clusters of anastomosing channels, cut off meanders, marshes, oxbow lakes, low level localized terraces and thus appear to be zone of perpetual active channel oscillation.

The Yamuna comprises the main drainage system in the study area flowing towards southerly direction turning gradually in the south to south-eastward direction between Okhla and Manjhauli. This stretch is highly braided and show, profuse development of anastomosing channels. The change in the trend of the river may possibly due to steepening of the slope of the river. Denudational processes are another significant agency engaged in sculpturing the land forms. The closely spaced intersecting joints help in the percolation of water resulting in leaching of cementing material, leaving behind a gritty and coarse quartzite. The close spaced joints and weathering through exfoliation and subsequent widening of joints by water action could have resulted in the occurrence of large ferrugenous boulders over the parent outcrop.

The river Yamuna, which makes the southwestern boundary mainly, recharges groundwater bodies of the study area only during flood period. During the heavey monsoon, the subsurface drainage gets reactivated in such saturated areas causing flooding and inundation in the area. The river Hindon is draining to the central portion of the area. The eastern and southeastern portion is dominated by the presence of canals and drains. Besides these, the surface water bodies are also responsible for the recharge of the aquifers and their concentration is found more in northern portion. The major source of the recharge of the ground water bodies in the upper Ganga canal which flows through eastern end of Greater Noida.

The area falls under the sub-tropical climatic zone with extremes summer and winter. The temperature rise upto 44°C or even more during May. The average rainfall in Ghaziabad is about 871.46 mm. The precipitation arises from south west monsoon and accounts for nearly 80 to 90% of annual rainfall. The remaining 10 to 20% of rainfall occur from January to March.

Noida, and Ghaziabad districts are parts of Ganga – Yamuna doab located adjacent to Union Territory of Delhi. The basin is rich in the development of agriculture as well as in industrial domain. It covers an area of about 2596 sq.km. The total population of Noida and Ghaziabad as per 2004 census has been estimated about 20.5 lakh respectively. The total area considered for land utilization in Ghaziabad is estimated as 2,59,455 hectare as per the statistical records available for the year 2006.

Geologically, the Bundelkhand Granite complex forms the basement. The basement complex underwent block faulting generating thereby a central horst and two grabans designated as East and West U.P. shelves. On the eroded surface of this basement the upper Vindhyans were deposited probably during the upper Proterozic era. Thereafter, it underwent post-Vindhyan faulting and erosion, since Cambrian to lower Miocene. During this long span of time (encompassing about 500 million year) the Vindhyan topography was reduced to almost peneplain and on these eroded surface Neogene Siwaliks were deposited which was latter on followed by the deposition of Quarternary Alluvium. This Quaternary deposit healed up the earlier depression through rapid sedimentation giving thereby a broad monotonous level expanses which is the present Ganga-Yamuna basin. The thickness of Quaternary sediments increases due North and attains the maximum thickness close to the Himalaya foothills. Quaternary alluvial deposits laid down by the action of river Yamuna. These Quaternary deposits of recent to sub –recent ages are underlain by the rocks of Delhi Super Group. Younger alluvium is separated by older one on the basis of darker tone, smooth texture, intense cultivation, thick forestation and association with river.

The study area is the part of great alluvial tract of the Indo-Gangetic alluvial plain. The Indo-Gangetic plain is supposed to be one of the best ground water reservoirs of the country. The alluvium consists of the older and newer alluvium of Pleistocene to recent age. The deposits are derived from the denudation and erosion of sedimentary and metamorphic rocks.

Overlying unconformably the folded and faulted Precambrian Alwar quartzite are deposits of alluvium of Quarternary age over a major part of the area. The alluvial sediments comprises a sequence of clay, silt, different grades of sand, gravel and kankar (calcareous nodules) in varying proportions. The borehole records suggest a maximum thickness of atleast 150 mt for this formation at Noida and about 500 to 600 mt at Ghaziabad. The deposits are river laid, lenticular in shape with thickness increases towards east and southeast.

The lithologs of the tubewells drilled in Noida show that the alluvium within 40 to 50 m depth comprises mainly of sand with clay and kankar intercalations and is predominantly clayey at deeper levels. Gravel and calcium carbonate concretions are quite common at shallow depth as thin beds and lenses or as nodules disseminated in clay. A hiatus in sedimentation or change in climatic conditions may be responsible for the kankar development in different horizons. The clay sand thickness ratio down to the depth range of 70 – 80 m showed normal distribution. However, at greater depth a different distribution suggests changes in the depositional regime. The Quarternary alluvial deposits are considered to be fluvial in origin.

On observation of the fence diagram, it is clear that, there exists a multi-aquifer system in the research area. The top aquifer is unconfined in nature. Alternate clay and kankar beds indicate the deeper aquifers to be leaky confined in nature, fine to medium grained sand constitute the aquifer material in general. Layers of coarse sand are met occasionally in the area. Two or three layers of aquifer, ranging in total thickness 15 to 20 mts. have been observed at ***Kulesra, Surajpur, Khodnakhurd*** and ***Sakipur*** area.

Alluvial deposits are highly porous and permeable because of the presence of sand and kankar. Groundwater occurs in the pore spaces of alluvial sediments in the zone of saturation. In alluvium, sand and silt-kankar form potential aquifer zones which generally occur within 40 metre to 50 metre depth. Groundwater occurs under phreatic condition at shallow depth whereas at greater depth it occurs under confined conditions. The thickness of alluvium comprising silt, sand, gravel and kankar in varying proportions increases from about 25 m in the area close to quartzite outcrops in the northwest to over 150 m in the south-eastern part of the area. The presence of highly porous materials in the shallow aquifer zone as compared to deep aquifers zone, the shallow aquifer have better yield characteristics. There are large number of tubewells in the vicinity of Noida area, constructed for irrigation, drinking and domestic purposes. These tubewells taped water from water bearing zone within 70 m to 80 m depth and yield 375 litre per minute to 1500 litre/minute for 5 to 10 m of drawdowns.

In Ghaziabad, shallow aquifers down to 125 m depth yield 1500 to 2500 litre/minute, whereas deeper aquifers comprising mainly medium to fine with occasional coarse grained sand below 150 m yield 2500 to 3500 liter/minute. The average transmissivity of shallow and deeper aquifers is 150 m^2/day and 1700 m^2/day respectively. The study revealed a general variation in depth to water level from 3.5 mts to 12.2 mts on a well (near *Sikandrabad*). The detailed survey revealed that, the depth to water level in the entire region, is observed within a range of 4 mts to 8 mts.

The depth to water level in the area ranges between 2-9.2 m to 12.65 m below the ground level. It is observed that during premonsoon period 26.14% of well shows depth to water level ranging between 8 to 16 mbgl and 10.76% wells are reported to have water level of 0 m to 4 mbgl in the year 2006 and in 2007 premoonsoon 9.22% of well shows depth to water level ranging between 8 to 16 mbgl and 60% are between 4 to 8 m. The water level during the post-monsoon period varied from 2.20 to 12 m mbgl. During the post-monsoon period 2006-07 the shallowest water level 2.20 mbgl were recorded at ***Chora Sadatpur*** and deepest 12 mbgl at ***Sikandrabad***. The seasonal fluctuation in water level varies from 0.17 to 1.7 m in 2006 and 0.22 to 2.33 m in 2007.

The rapid industrialization, urbanization and anthropogenic activity in the study area have caused Geo-environmental degradation of land, change in ecological balance, rapid increase in environmental pollution and decline in the available natural resources of the region. Environmental impact due to brick kilns, mining, water logging, canal induced seepage and also because of shallow water table, flooding during heavy rain fall, poor drainage system and unplanned development of unauthorized colonies near the flood plains.

A large number of industries located in the area discharging their effluents without proper treatment into the Yamuna and Hindon river and the solid waste from the factories in the depression, consequently polluting the surface and sub surface water. The pollutants generated from these sources more primarily downwards from the surface through unsaturated zone and solute undergoes only a small degree of horizontal displacement. As soon as the pollutant reaches the saturated zone, it follows the direction of groundwater flow and spreads over a large area in ground water system. Ground water occurs under semi-confined to confined condition.

The chemical quality of water around **Ghazipur sanitary landfill** site has been taken up to evaluate its suitability for drinking purpose. Water in the area is hard, alkaline in nature, and having high salinity. Over all the concentration of major ions and total hardness are above the permissible limit of WHO (1993). The chemical analysis for heavy metals revealed that some of toxic metals present in the water are higher than tolerance limits of WHO (1993). The recovery of methane gas has been carried out from sanitary landfill site of Ghazipur in sufficient quantity, which may be useful for the production of electricity.

The chemical quality of water in parts of Yamuna river sub basin has been taken up from the analysis of 120 ground water samples for the study to evaluate it suitability for irrigation and drinking purposes. In general, the groundwater is alkaline in nature and overall salinity of water in the area is generally high.

The pH value of the pre-monsoon ranges from 6.2-9.6 with an average of 7.89, and in post-monsoon 6.1 to 9.6 with an average of 7.8, thereby showing alkaline nature of water. Electrical conductivity is high in the study area with a range of 150-2800 μS/cm. The higher concentrations of TDS have been recorded from ***Sikandrabad*** (1728 mg/l, 1792 mg/l) ***Rajpur Khurd*** (1600 mg/l, 1664 mg/l), ***Kotdhari*** (1408 mg/l, 1344 mg/l) and Pali (1344 mg/l, 1472 mg/l). Water with high concentration of TDS is laxative effect on people.

The hardness of water in the study area ranged from 221.14 to 498.78 mg/L (pre-monsoon) and 173.60 to 466.97 mg/L (pos-tmonsoon). With an average of 356.05 mg/L and 319.37 mg/L. In general, water of the area is hard. Maximum value was recorded at ***Khodna Khurd*** (498.78 mg/L) in pre-monsoon.

The chloride (Cl^-) concentration ranged from 98 to 412.6 mg/L with an average 228.94 mg/L in the pre-monsoon and 16 mg/l to 392 mg/L with an average 211.18 mg/L in post-monsoon water samples. High concentration of chloride is confined in ***Bahlapur*** (412.6 mg/L and 392 mg/L) and in ground water of ***Mandoli, Chiyana Buzurg, Bhopani*** and ***Mahanpur***.

Calcium (Ca^{++}) contents in ground water of the area ranged from 30.5 to 86.8 mg/L in pre-monsoon and 27.7 mg/l to 85.6 mg/L in post-monsoon. The maximum permissible limit of WHO (1993) is 200 mg/L. The high concentrations (277.3 mg/l) of calcium have been observed at Ghori Bachera. Calcium has tendency to get precipitated in the form of concentrations known as kankar. During contact with clays, part of calcium may also undergo ion-exchange reaction, which may be the reason for the depletion of calcium in ground water. Higher concentration of magnesium have been observed at ***Khondana Khurd, Surajpur*** and ***Manchala*** ranged from 30.4 to 70.8 mg/L in pre-monsoon and 22.6 to 65.6 mg/L in post-monsoon.

The highest value of Sodium (Na) has been recorded at ***Bulandshahar road industrial area*** (556 mg/L) and ***Lal Kuan Industrial area*** (518 mg/L). The guideline value of sodium is given as 200 mg/L which is based on taste consideration (WHO, 1993). The concentration of potassium in the area is under the permissible limit, (WHO 1993) except few places ranging between 12 to 82 mg/L.

Concentration of sulphate (SO4) in the area ranged from 26 to 786.3 mg/L in pre-monsoon and 122 to 777 mg/L in post-monsoon. WHO, 1993 have prescribed highest desirable limits of SO_4 is 200 mg/L and maximum permissible limit of 400 mg/L. ***Jamalpur, Grdhnur*** and ***Rajput Khurd*** where the concentration of sulphate is above the permissible limit of WHO (1993), 786.3 mg/l, 532.5 mg/l and 770 mg/l respectively.

The range of bicarbonate (HCO_3) concentration is from 112 mg/l to 1212 mg/L in and 112 mg/l to 1106 mg/L in post-monsoon with an average of 323.8 and 297.61 mg/L. The maximum concentration (1212 mg/l) was observed in the ***Jamalpur***. Highest concentration of carbonate (256 mg/L) have been recorded at ***Dankaur***.

Iron (Fe) concentration in ground water varies from 0.003 to 1.731 mg/L with an average of 0.570 mg/L. The over all distribution of iron is above the permissible limits (0.1 mg/L WHO, 1993) for drinking water supplies. The higher concentrations of iron have been observed at ***Bulandshahr*** industrial area and ***Bahlapur, Makhanpur, Near Hindon River, Salarpur Khadar*** and ***Bangel.***

The highest value of Manganese (Mn) has been recorded (0.894 mg/L) at ***Kotdhari***. The concentration of manganese ranges from 0.04 to 0.894 mg/L with an average of 8.377 mg/L.

In the study area lead (Pb) concentration in ground water are generally high with an average value of 0.155 mg/L. The maximum permissible limit of lead (Pb) 0.01 mg/L as reported by (WHO, 1993). Maximum concentration of lead (Pb) (0.321mg/l) has been observed at ***Dankaur, Wair, Sikandrabad*** and ***Rajpur***. Copper (Cu) concentration in ground water ranged between 0.004 mg/L and 0.259 mg/L average 0.259 mg/L. Zinc (Zn) in the ground water in the study area may be contributed by industrial effluents like electroplating wastes containing high level of zinc. Zinc concentration in the ground water ranged from 0.004 mg/L to 6.239 mg/L average 1.954 mg/L.

The concentration of cadmium (Cd) in the study area ranges from 0.002 mg/L to 3.50 mg/L with an average of 0.168 mg/L. In most of the samples, they are within the permissible limit of WHO, 1993 (0.005 mg/L) but in the areas close to the Hindon river and around the industrial area, the concentration of Cadmium (Cd) exceeded the permissible limit of WHO, 1993. The major source of cadmium (Cd) in the study area are effluents of industries connected with electroplating, copper and nickel alloys, paints, nickel-cadmium batteries etc.

Chromium (Cr) concentrations in ground water ranged from 0.003 to 0.382 mg/L with an average of 0.061 mg/L. In some samples, it is below detection limit. WHO (1993) has prescribed 0.054 mg/L of chromium (Cr) as the maximum permissible limit. Highest concentration of chromium (Cr) have been observed in ***Bhopani a industrial area*** of Noida. Chromium in the area is used in metallurgical industry. It is also used in electroplating, chemical and Dyes industries.

The chemical analysis of ground water for heavy metals revealed that some of the toxic metals (Cd,Cr,Pb) present in ground water are more then the concentration of WHO (1993) permissible limit. The wide spread practice of dumping raw sewage in shallow soak pits has made apprehension of pollution of ground water in the area. Abnormally higher levels of trace elements are found near the industrial areas indicating the effects of effluents on ground water.

Twenty five samples soil samples have been analyzed for major and trace elements. The concentrations of heavy metals in the soil samples are comparatively higher than the water. The maximum concentration of trace elements have been recorded in the soil samples collected from ***Lal Kuan industrial area*** and ***Tusiana*** and ***Makhanpur***.

In order to designate hydrochemical facies of the study area Morgan and Winner (1962) and Back (1966). The plotting of analytical results shows that sodium or potassium are the dominant facies among the cations. About 54% of the samples in premonsoon and 88% in post-monsoon samples analysed to fall in sodium, potassium type facies, only seven samples fall in calcium type facies and the six in pre-monsoon and seven in post-monsoon in no dominant type of facies. Among the anion facies, majority of the samples fall in no dominant type facies followed by sulphate and bicarbonate type facies. Few samples belong to chloride type.

The electrical conductivity and sodium adsorption ratio are plotted on U.S. salinity diagram which gives direct indication of the salinity and alkali hazard. The salinity hazard increase as the soils become finer grained and aridity increase resulting in the concentration of salt in the soil that may require periodical leaching. Excessive sodium content in water renders it unsuitable for soils containing exchangeable calcium and magnesium. The plotted data shows that most of the sample of premonsoon and post-monsoon belongs to the category C_3S_1 and C_3S_2 which falls within the zone of moderate to good quality class, which indicate low alkali hazard and high salinity hazard. The values of sodium percentage against E.C. are plotted on Wilcox diagram, reveals that there is a variation in the water quality of study area. About 33% in pre- and 36% in post-monsoon belongs to permissible to doubtful and 20% of the samples falls in unsuitable class.

Gibbs (1970) variation diagram has been used to study the mechanism controlling water chemistry. It is observed that the water chemistry of the area occupies the field of rock dominance indicating that the major mechanism controlling the water chemistry is the weathering of rocks.

Correlation coefficients among various chemical variables have been determined to study the relationship among quality parameters. The highest positive correlation has been found between electrical conductivity and total dissolved solids. The positive correlation has been observed in values of EC, TDS with Cl, Na and K in pre-monsoon water samples with EC, TDS and total hardness with Cl, Na, Mg and K. In post-monsoon water samples showed highest negative correlation between pH, EC and TDS in pre-monsoon and TDS and SO_4. The high correlation was also observed between Na, K and Cl in post-monsoon samples.

An attempt has also been made to evaluate the possible factors controlling variation in groundwater chemistry and to infer possible changes that occur in two time periods that is post and pre-monsoon groundwater quality. A number of X-Y plots were prepared between Na+K – Ca+Mg, HCO_3 – Ca+Mg, HCO_3 - Cl + SO_4, Na+K-Cl, Ca+Mg-HCO_3 and Ca-SO_4 for deciphering various chemical alteration trends of groundwater and suggest that alkalies are more abundant than Ca and Mg.

On the basis of plot HCO_3^- vs $Cl^-+SO_4^-$ reveals that the groundwater in the area is classify into two groups i.e. $HCO_3^- > Cl^- + SO_4$ and $Cl\text{-}+SO_4^- < HCO_3$. $Ca^{++}+Mg^{++}$ and HCO_3 plot suggest a moderately good correlation of pre- and post-monsoon samples. Na-SO_4-HCO_3 type facies is more evolved in ion exchange reaction and SO_4^{--} relation enrichment in the groundwater of the study area.

Ground water pollution in the basin is mainly due to indiscriminate disposal of industrial wastes on land and surface water channels. Present investigation has revealed that the ground water is characterized by high content of pollutants as evident from high concentrations of toxic metals. Water pollution from various industries can be minimized easily if steps are taken at the stage of planning and preparation of project by selecting proper site and appropriate technology.

Keeping in view of the declining water level at places due to excessive withdrawal and deterioration in ground water quality, it is suggested that measures are to be taken to stop further exploitation of ground water and continuous monitoring and ameliorative schemes should be implemented in groundwater resources.

Pollution load from industrial and urban centers can be minimized by installing proper waste treatment and disposal system. Stabilization of ecosystem which involves reduction in waste input, removal of biomass, fish management and aeration is the most reliable measures to control water pollution. Recycling and reutilization of waste is another way to control water pollution. Various kinds of wastes such as paper, pulp, municipal and urban waste can be recycled to generate cheaper fuel gas and electricity can be implemented in the area of study.

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APPENDICES

APPENDIX II A: Monthly rainfall data of eleven years (1996-2006) in (mm).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1996	42	6	-	223	3	20	412	370	107	-	-	4	1187
1997	2	10	-	-	-	40	235	215	98	-	-	-	600
1998	-	-	-	-	22	33	345	263	143	46	-	37	889
1999	34	27	41	-	24	150	76	131	72	-	-	12	567
2000	16	13	7	-	17	57	26	96	11	-	-	-	243
2001	-	5	42	8	-	59	216	374	79	1	-	4	788
2002	36	-	40	-	1	12	27	134	156	-	-	20	426
2003	-	111	9	-	63	16	219	136	190	6	24	5	779
2004	-	-	-	-	-	-	-	-	-	-	-	-	-
2005	63	30	-	-	-	21	278	281	41	8	22	-	744
2006	16	16	9	-	8	104	143	64	220	-	-	-	580
Average	**20.9**	**21.8**	**14.8**	**23.1**	**13.8**	**51.2**	**197.7**	**206.4**	**111.7**	**6.1**	**4.6**	**8.2**	**680.30**

Source: District Office, Ghaziabad.

Appendix IIB: Departure and Cumulative departure

Mean of 11 years of rainfall (X) = 680.30

Standard deviation = 247.17

Coefficient of variation = 36.33%

S. No	Years	Annual Rainfall(X)	(X – X)	Departure	Cumulative Departure
1	1996	1187	506.7	+0.74	+0.74
2	1997	600	-80.3	-0.12	+0.62
3	1998	889	208.7	+0.31	+0.93
4	1999	567	-113.3	-0.17	+0.76
5	2000	243	-437.3	-0.64	+0.12
6	2001	788	107.7	+0.16	+0.28
7	2002	426	-254.3	-0.37	-0.09
8	2003	779	98.7	+0.15	+0.06
9	2004	-	-	-	-
10	2005	744	63.7	+0.09	+0.15
11	2006	580	-100.3	-0.15	0.00

Appendix-IVA: Hydrogeological data of observation wells in part of Yamuna river sub-basin (June – Nov. 2006)

S. No.	Location	Well No.	Ground level (m)	Pre-monsoon		Post-monsoon		Water level fluctuation
				Water level (m.b.g.l.)	Water table (m.a.m.s.l.)	Water level (m.b.g.l.)	Water table (m.a.m.s.l.)	
1	2	3	4	5	6	7	8	9
1.	Surya Nagar	W-1	206.25	7.45	198.80	7.00	199.25	0.45
2.	Sahibabad	W-2	205.00	8.12	196.88	7.95	197.05	0.17
3.	Temple Near Hindon River	W-3	208.08	6.17	201.91	5.90	202.18	0.25
4.	Mandaoli	W-4	205.00	7.23	197.77	6.90	198.10	0.33
5.	Makanpur	W-5	202.70	4.00	198.70	3.35	199.75	0.65
6.	Chhajarsi	W-6	200.00	5.60	194.40	5.50	194.50	0.10
7.	Tigri	W-7	200.68	6.00	194.68	5.60	195.08	0.40
8.	Behrampur	W-8	204.84	5.95	198.89	5.20	199.64	0.475
9.	Kinouni	W-9	200.00	5.50	194.50	5.00	195.00	0.50
10.	Amritanagar	W-10	209.00	9.96	199.64	9.76	199.84	0.20
11.	Banheta	W-11	210.00	10.50	199.50	10.00	200.00	0.50
12.	Ghazipur Dairy	W-12	202.25	10.24	192.01	8.75	193.50	1.49

1	2	3	4	5	6	7	8	9
13.	Chora Sadatpur	W-13	200.00	3.00	197.00	2.20	197.00	0.80
14.	Bahlapur	W-14	200.00	5.75	194.25	5.55	194.45	0.20
15.	Chiplyana Buzurg	W-15	209.56	8.02	201.55	7.15	202.42	0.87
16.	Bishnouli	W-16	210.00	3.00	207.00	2.30	207.70	0.70
17.	Rauza Jalalpur	W-17	209.99	Dry	-	Dry	209.99	-
18.	Naurangabad	W-18	199.50	Dry	199.50	Dry	199.50	-
19.	Chhalera Bangar	W-19	200.00	4.91	195.09	4.73	195.27	0.18
20.	Salarpur Khadar	W-20	199.45	4.25	195.20	4.15	195.30	0.10
21.	Bisrakh	W-21	203.75	6.15	197.60	4.75	199.00	1.40
22.	Tusiyana	W-22	209.85	8.67	201.18	4.75	201.65	3.92
23.	Manikpur	W-23	-	Dry	-	Dry	-	-
24.	Kheri	W-24	210.00	9.10	200.90	7.81	202.19	1.29
25.	Raipur Khadar	W-25	199.85	3.94	195.91	2.50	197.35	1.44
26.	Sultanpur	W-26	198.68	4.90	193.78	4.57	194.11	0.33
27.	Ashganpur	W-27	198.50	4.46	194.04	3.84	194.66	0.62
28.	Gejah	W-28	200.00	5.40	194.60	3.70	196.30	1.70

1	2	3	4	5	6	7	8	9
29.	Nagla Charandas	W-29	199.85	4.73	195.12	4.12	195.73	0.61
30.	Gejah	W-30	198.45	Dry	198.45	Dry	193.89	-
31.	Suthiana	W-31	198.00	Dry	198.00	Dry	195.15	-
32.	Surajpur	W-32	198.86	3.20	195.66	2.23	196.63	0.97
33.	Tilnpra	W-33	210.00	6.10	203.90	4.34	205.66	1.76
34.	Tilnpra	W-34	210.00	7.56	202.44	7.24	202.76	0.32
35.	Tilnpra	W-35	210.00	7.10	202.90	4.95	205.05	2.15
36.	Pali	W-36	208.96	8.15	200.81	6.95	202.01	1.20
37.	Kotderi	W-37	210.05	8.05	202.00	7.25	202.80	0.80
38.	Kotderi	W-38	210.05	6.90	203.15	5.90	206.50	1.00
39.	Agwanpur	W-39	195.70	8.37	187.33	7.80	187.90	0.57
40.	Yaqutpur	W-40	196.50	8.10	188.40	6.15	190.35	1.95
41.	Jhatta	W-41	195.70	7.45	188.25	5.95	189.75	1.50
42.	Surajpur	W-42	196.36	2.95	193.41	2.69	193.67	0.26
43.	Bahmanpur Gujrala	W-43	202.00	6.39	195.61	4.65	197.35	1.74
44.	Gohri Bachchera	W-44	206.50	8.95	197.55	7.15	199.35	1.80

1	2	3	4	5	6	7	8	9
45.	Ajaibpur	W-45	206.85	7.64	199.21	5.15	201.70	2.49
46.	Bhopani	W-46	200.00	9.31	190.69	8.12	191.88	1.19
47.	Rajpur	W-47	200.00	6.96	193.04	6.96	194.20	0.00
48.	Badoli	W-48	195.80	8.07	187.73	6.75	189.05	1.32
49.	Tughalpur	W-49	198.16	Dry	-	Dry	196.06	-
50.	Dattha	W-50	202.25	2.92	199.33	2.62	199.63	0.30
51.	Pachayatan	W-51	206.75	Dry	-	Dry	203.03	-
52.	Raipur Kalan	W-52	205.45	6.03	199.42	4.95	200.50	1.08
53.	Sikandrabad	W-53	208.00	12.05	195.95	12.00	196.00	0.05
54.	Dhaikora	W-54	202.00	Dry	-	Dry	195.82	-
55.	Attai	W-55	195.50	5.40	190.10	4.50	191.00	0.90
56.	Naya Gharbara	W-56	195.00	5.15	189.85	3.90	191.10	1.25
57.	Daudpur	W-57	201.56	5.25	196.31	3.95	197.61	1.30
58.	Bilaspur	W-58	203.55	7.45	196.10	6.30	197.25	1.15
59.	Jamalpur	W-59	203.00	7.37	195.63	5.80	197.20	1.57

1	2	3	4	5	6	7	8	9
61.	Atta Gujran	W-61	193.50	6.70	186.80	5.37	188.13	1.33
62.	Dankaur	W-62	200.00	6.90	193.10	5.45	194.55	1.45
63.	Kanarsa	W-63	202.14	10.79	191.35	9.95	192.19	0.84
64.	Hirnoti	W-64	202.00	6.35	195.65	5.85	196.15	0.50
65.	Wair	W-65	204.00	5.95	198.05	5.00	199.00	0.95

Appendix-IVB : Hydrogeological data of observation wells in part of Yamuna river sub-basin (June – Nov. 2007)

S. No.	Location	Well No.	Ground level (m)	Pre-monsoon		Post-monsoon		Water level fluctuation
				Water level (m.b.g.l.)	Water table (m.a.m.s.l.)	Water level (m.b.g.l.)	Water table (m.a.m.s.l.)	
1	2	3	4	5	6	7	8	9
1.	Surya Nagar	W-1	206.25	7.95	198.30	8.65	197.60	-0.70
2.	Sahibabad	W-2	205.00	7.4	197.60	6.55	198.45	0.85
3.	Temple Near Hindon River	W-3	208.08	6.88	201.20	6.05	202.03	0.83
4.	Mandaoli	W-4	205.00	7.55	197.45	7.00	198.00	0.55
5.	Makanpur	W-5	202.70	4.00	198.70	3.78	198.92	0.22
6.	Chhajarsi	W-6	200.00	4.79	195.21	4.24	195.76	0.55
7.	Tigri	W-7	200.68	5.92	194.76	5.26	195.42	0.66
8.	Behrampur	W-8	204.84	5.97	198.87	5.32	199.52	0.65
9.	Kinouni	W-9	200.00	5.25	194.75	4.63	199.37	0.62
10.	Amritanagar	W-10	209.00	9.27	200.33	8.45	201.15	0.82
11.	Banheta	W-11	210.00	8.91	201.09	8.13	201.87	0.78
12.	Ghazipur Dairy	W-12	202.25	Dry	-	Dry	-	-

1	2	3	4	5	6	7	8	9
13.	Chora Sadatpur	W-13	200.00	3.10	196.90	2.34	197.66	0.76
14.	Bahlapur	W-14	200.00	5.54	194.46	4.85	195.15	0.60
15.	Chiplyana Buzurg	W-15	209.56	3.68	205.89	3.08	206.49	0.60
16.	Bishnouli	W-16	210.00	Dry	-	Dry	-+	-
17.	Rauza Jalalpur	W-17	209.99	Dry	-	Dry	-	-
18.	Naurangabad	W-18	199.50	Dry	-	Dry	-	-
19.	Chhalera Bangar	W-19	200.00	4.78	195.22	4.21	195.79	0.57
20.	Salarpur Khadar	W-20	199.45	4.25	195.20	4.15	195.30	0.85
21.	Bisrakh	W-21	203.75	5.00	198.75	4.78	198.97	2.22
22.	Tusiyana	W-22	209.85	7.00	202.85	6.42	203.43	0.58
23.	Manikpur	W-23	-	Dry	-	Dry	-	-
24.	Kheri	W-24	210.00	8.92	201.08	7.89	202.11	1.03
25.	Raipur Khadar	W-25	199.85	3.92	195.93	2.69	197.16	1.23
26.	Sultanpur	W-26	198.68	4.68	194.00	4.18	194.50	0.50
27.	Ashganpur	W-27	198.50	3.98	194.52	3.36	195.14	0.62
28.	Gejah	W-28	200.00	4.69	195.30	4.58	195.42	0.11

1	2	3	4	5	6	7	8	9
29.	Nagla Charandas	W-29	199.85	4.36	195.49	3.67	196.18	0.69
30.	Gejah	W-30	198.45	3.89	194.56	3.29	195.16	0.60
31.	Suthiana	W-31	198.00	3.28	194.72	2.78	195.22	0.50
32.	Surajpur	W-32	198.86	3.21	195.65	2.26	196.60	0.95
33.	Tilnpra	W-33	210.00	5.05	204.95	4.15	205.85	0.90
34.	Tilnpra	W-34	210.00	7.20	202.80	6.82	203.18	0.38
35.	Tilnpra	W-35	210.00	5.12	204.88	4.10	205.90	1.02
36.	Pali	W-36	200.96	7.65	201.31	6.70	202.26	0.95
37.	Kotderi	W-37	210.05	7.80	202.25	6.83	203.35	0.97
38.	Kotderi	W-38	210.05	6.70	-	5.78	206.50	0.92
39.	Agwanpur	W-39	195.70	7.95	187.75	7.33	188.37	0.62
40.	Yaqutpur	W-40	196.50	8.00	188.50	6.54	189.96	1.46
41.	Jhatta	W-41	195.70	7.40	188.30	5.98	189.72	1.42
42.	Surajpur	W-42	196.36	2.95	193.41	2.60	193.76	0.35
43.	Bahmanpur Gujrala	W-43	202.00	4.90	197.10	3.70	198.30	1.20
44.	Gohri Bachchera	W-44	206.50	8.60	197.90	6.88	199.62	1.72

1	2	3	4	5	6	7	8	9
45.	Ajaibpur	W-45	206.85	7.65	199.20	5.10	201.75	2.55
46.	Bhopani	W-46	200.00	8.95	191.05	7.45	192.55	1.50
47.	Rajpur	W-47	200.00	6.81	193.19	5.66	194.34	1.15
48.	Badoli	W-48	195.80	6.00	189.80	4.85	190.95	1.15
49.	Tughalpur	W-49	198.16	Dry	-	Dry	-	-
50.	Dattha	W-50	202.25	3.20	199.05	2.81	202.25	0.39
51.	Pachayatan	W-51	206.75	Dry	-	Dry	-	0.32
52.	Raipur Kalan	W-52	205.45	6.00	199.45	4.90	205.45	1.90
53.	Sikandrabad	W-53	208.00	12.32	195.68	12.00	208.00	0.32
54.	Dhaikora	W-54	202.00	Dry	-	Dry	-	-
55.	Attai	W-55	195.50	6.48	189.02	5.78	195.50	2.33
56.	Naya Gharbara	W-56	195.00	5.00	190.00	4.15	190.85	0.85
57.	Daudpur	W-57	201.56	5.38	196.18	4.14	197.42	1.24
58.	Bilaspur	W-58	203.55	7.05	196.50	Dry	197.50	1.00
59.	Jamalpur	W-59	203.00	Dry	-	6.05	196.02	-
60.	Chiti	W-60	205.75	8.53	197.22	6.98	201.10	1.55

1	2	3	4	5	6	7	8	9
61.	Atta Gujran	W-61	193.50	5.85	187.65	4.65	187.86	1.20
62.	Dankaur	W-62	200.00	6.95	193.05	5.64	194.36	1.31
63.	Kanarsa	W-63	202.14	Dry	-	Dry	-	-
64.	Hirnoti	W-64	202.00	6.40	195.60	5.90	196.35	0.50
65.	Wair	W-65	204.00	6.20	197.80	5.65	204.00	0.55

Appendix VII A : Physicochemical and Hydrochemical data of the Pre-monsoon 2006 groundwater samples (mg/L)

Sl. No.	Location	Source	pH	EC	Hardness	TDS	Ca^{++}	Mg	Na	K	HCO_3	CO_3	Cl^-	SO_4^{--}	NO_3
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Surya Nagar	HP	7.7	1300	325.21	832	55.3	45.6	168	72	188	82	219.2	182	15
2.	Sahibad Industrial Area	HP	6.9	800	293	512	47.5	42.5	472	64	312	113	186.8	186.2	25
3.	Temple Near Hindon River	HP	6.7	1200	286.39	768	48.3	40.4	166	18	418	172	192.9	216.9	18
4.	Makanpur	HP	7.4	700	351.23	448	45.7	57.8	214	16	169	114	219.6	189.8	22
5.	Behrampur	HP	7.3	900	374.26	576	53.6	58.6	316	44	219	82	216.5	168.6	35
6.	Banheta	TW	8.4	1200	362.44	768	65.6	48.4	164	52	156	52	356.8	312.6	15
7.	Ghazipur Dairy	HP	8.1	150	333.69	96	70.5	38.4	176	52	183	44	312.6	414	18
8.	Meerut Road Industrial Area	HP	6.8	700	236.56	448	42.8	31.6	478	78	196	56	268	189	26
9.	Lal Kuan Industrial Area	HP	6.7	600	248.33	384	43.9	33.8	518	62	196	64	342	212	45
10.	Bulandshare Road Industrial Area	HP	6.2	700	226.95	448	38.3	32.	556	64	369	92	266.9	612	27
11.	Mandaoli	TW	7.4	900	314.41	576	55.9	42.6	322	26	252	78	316.5	286	52
12.	Bahlapur	TW	7.5	500	303.38	320	52.8	41.8	228	32	122	56	412.6	312	18

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
13.	Chiplyana Buzurg	TW	7.8	600	260.01	384	48.9	33.6	216	64	275	95	316.5	128	16
14.	Habatpur	HP	7.8	1000	333.33	640	61.5	43.8	126	18	189	42	119.6	252	18
15.	Chora Sadatpur	TW	7.9	1200	340.72	768	63.8	44.2	414	14	400	28	182	260	26
16.	Nayabas	TW	8.2	1800	429.81	1152	70.9	61.6	122	48	279	56	196	268	39
17.	Chhalera Bangar	HP	7.6	1500	296.12	960	55.8	38.2	116	52	186	61	232.6	262	42
18.	Salarpur Khadar	HP	8.6	2100	388.49	1344	75.2	48.9	152	52	165	22	218.8	378	35
19.	Bhangel Begahpur	HP	8.9	2200	480.97	1408	78.9	69.2	272	16	475	92	161.6	356	46
20.	Gejah	TW	8.3	1900	330.58	1216	68.6	38.8	162	48	262	59	281.6	672	32
21.	Rauza Jalalpur	TW	7.5	800	254.96	512	43.6	35.6	168	52	286	63	292.5	384	35
22.	Bisrakh	HP	7.8	700	265.66	448	52.8	32.6	216	36	336	48	248	189	18
23.	Ahlnabad	HP	8.8	2000	330.87	1280	69.7	38.2	416	16	172	64	262	166	16
24.	Tusiyana	TW	8.6	1800	403.15	1152	68.6	56.5	132	18	269	71	182.8	182	12
25.	Kulesra	TW	8.7	1500	442.76	960	72.8	63.6	144	26	183	59	282	192	38
26.	Khodnakhurd	TW	9.2	2300	498.78	1472	83.4	70.8	540	44	282	48	245	212	12
27.	Tilapta	TW	7.8	1700	429.06	1088	70.6	61.6	232	66	144	62	286.8	246	59
28.	Pali	TW	8.2	2100	402.66	1344	74.8	52.6	262	70	232	48	242.6	414	16

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
29.	Sadpur	HP	7.7	1200	470.06	768	78.8	66.6	142	72	186	84	258.8	312	65
30.	Surajpur	HP	8.4	1500	491.82	960	81.6	70.2	376	48	379	24	216.5	362	16
31.	Ghori Bachera	HP	9.4	2400	489.65	1536	86.8	66.5	252	32	1212	63	281.2	575	12
32.	Brandi	HP	7.8	800	366.41	512	60.3	52.6	122	36	268	61	126	161.6	16
33.	Bahmanfur	HP	7.9	1100	338.12	704	56.2	48.2	186	62	272	76	176	182.5	11
34.	Tughalpur	HP	7.3	700	284.01	448	50.3	38.6	174	32	149	48	148	282.2	15
35.	Jhatta	HP	6.3	700	221.14	448	38.6	30.4	162	46	219	65	177	289.6	22
36.	Badoli	HP	6.6	800	277.42	512	35.2	46.2	114	56	276	128	182.6	362.2	27
37.	Yoqutur	HP	6.7	1000	285.99	640	34.2	48.9	118	52	316	116	126.5	386.5	27
38.	Bhopani	TW	6.5	800	223.82	512	31.8	35.2	138	48	386	65	312.5	237	33
39.	Rajpur Kalan	TW	6.2	600	286.17	384	38.7	46.2	142	58	139	49	169	26	35
40.	Dhnkora	TW	6.5	500	263.66	320	35.6	42.6	116	18	514	69	142	163	42
41.	Dadha	TW	7.8	1100	323.78	704	46.2	50.8	142	16	148	78	98	261.6	43
42.	Sirsa	HP	7.7	900	269.92	576	48.6	36.2	152	14	348	86	149	281.2	15
43.	Manhcha	HP	9.5	2500	455.14	1600	78.9	62.9	378	26	676	122	382.6	230.6	32
44.	Luksar	HP	7.4	700	307.56	448	54.8	41.6	178	52	189	65	146	168	16

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
45.	Chaharpur Khadar	HP	7.6	900	350.01	576	60.3	48.6	216	34	278	46	192	137	17
46.	Naya Gharbara	HP	7.8	1100	368.68	704	65.8	49.8	228	42	278	112	110	155	53
47.	Dadupur	TW	7.9	1500	417.99	960	70.6	58.9	232	12	182	67	142	188	57
48.	Grdhnur	HP	8.3	1900	415.74	1216	73.8	56.4	246	36	216	65	163	532.5	62
49.	Janalpur	HP	9.6	2700	487.85	1728	82.8	68.5	478	14	1124	106	378.2	786.3	65
50.	Blaspur	TW	8.2	1300	372.26	832	96.2	48.6	148	78	269	62	279.8	178	42
51.	Chiti	TW	8.4	1800	435.24	1152	73.4	61.4	415	48	368	68	261.6	308	41
52.	Astaula	HP	9.3	2100	484.22	1344	84.3	66.7	375	88	589	59	236.5	196	61
53.	Kanarsa	HP	8.2	1700	438.58	1088	70.8	63.8	128	64	475	49	172.6	226	25
54.	Chuharpur Bangan	TW	8.1	1500	440.25	960	73.6	62.5	178	48	172	42	312.8	312	18
55.	Atta Gujran	HP	6.8	900	234.1	576	30.5	38.5	415	28	168	68	216	479.6	56
56.	Dankaur	HP	7.9	1300	300.66	832	50.4	42.6	272	15	286	256	172	312	16
57.	Wair	HP	8.9	1900	361.88	1216	51.6	56.8	516	18	289	28	178	179	62
58.	Sikandarabad	HP	9.3	2700	473.74	1728	76.5	68.9	276	48	367	69	212	169	69
59.	Rajpur Khurd	HP	9.6	2500	452.16	1600	78.2	62.6	128	46	876	156	289.6	586.2	72
60.	Kotderi	TW	9.5	2200	431.16	1408	69.8	65.4	328	26	899	162	168	318.2	28
	Average		**7.89**	**1335**	**356.05**	**854.93**	**60.30**	**50.07**	**248.9**	**42.21**	**323.8**	**75.61**	**228.94**	**286.43**	**32.56**

Appendix VII B : Physicochemical and Hydrochemical data of the Post-monsoon 2007 groundwater samples (mg/L)

Sl. No.	Location	Source	pH	EC	Hardness	TDS	Ca^{++}	Mg	Na	K	HCO_3	CO_3	Cl^-	SO_4^{-}	NO_3
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Surya Nagar	HP	7.6	1200	298.93	1200	50.2	42.3	152	65	155	78	220	198	12
2.	Sahibad Industrial Area	HP	7.1	700	269.42	448	44.3	38.7	453	55	292	104	190	200	18
3.	Temple Near Hindon River	HP	6.5	1300	239.66	832	42.4	32.6	155	12	396	152	204	225	16
4.	Makanpur	HP	7.6	800	270.5	512	38.5	42.5	207	12	153	104	222	178	25
5.	Behrampur	HP	7.2	1000	343.77	640	43.7	57.2	294	35	200	86	204	150	30
6.	Banheta	TW	8.3	1100	316.93	704	57.4	42.3	152	44	136	56	360	320	13
7.	Ghazipur Dairy	HP	8.0	1300	291.64	832	66.8	30.4	165	48	153	50	302	428	20
8.	Meerut Road Industrial Area	HP	6.6	800	233.1	512	38.3	33.5	475	72	164	56	252	166	29
9.	Lal Kuan Industrial Area	HP	6.6	700	203.71	448	39.5	25.6	482	56	157	56	318	192	48
10.	Bulandshare Road Industrial Area	HP	6.4	600	196.75	384	33.6	27.5	532	65	319	76	236	588	25
11.	Mandaoli	TW	7.3	800	261.22	512	52.5	31.7	302	22	246	72	302	272	50
12.	Bahlapur	TW	7.2	500	250.78	320	45.7	33.3	216	25	112	52	392	278	16

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
13.	Chiplyana Buzurg	TW	7.9	500	226.63	320	42.6	29.3	200	38	256	92	304	112	12
14.	Habatpur	HP	8.1	900	324.57	576	55.7	45.2	130	15	176	45	115.2	260	22
15.	Chora Sadatpur	TW	8.5	1100	315.16	704	60.3	40.1	432	12	282	25	177	265	25
16.	Nayabas	TW	7.9	1700	359.99	1088	63.8	48.9	104	42	266	48	182	268	30
17.	Chhalera Bangar	HP	7.5	1400	266.05	896	48.2	35.5	108	46	178	56	204	282	45
18.	Salarpur Khadar	HP	8.2	2200	362.15	1408	68.6	46.5	142	48	159	18	210	406	32
19.	Bhangel Begahpur	HP	8.5	2300	445.21	1472	70.5	65.6	256	12	469	82	150	372	41
20.	Gejah	TW	8.1	1900	323.41	1216	63.6	40.1	152	42	246	56	265.2	650	27
21.	Rauza Jalalpur	TW	7.6	700	241.19	448	45.8	30.9	156	55	253	65	278	352	34
22.	Bisrakh	HP	7.7	600	243.47	384	53.6	26.7	204	30	302	42	235	162	14
23.	Ahlnabad	HP	8.5	2200	302.53	1408	70.5	30.8	435	14	153	58	225	170	10
24.	Tusiyana	TW	8.3	2000	368.13	1280	66.4	49.3	108	20	270	65	176	185	15
25.	Kulesra	TW	8.5	1300	402.64	832	70.2	55.4	132	28	168	52	278	208	30
26.	Khodnakhurd	TW	9.1	2100	466.97	1344	85.6	61.7	512	50	290	42	236	200	8
27.	Tilapta	TW	7.6	1500	385.64	960	67.5	52.9	200	58	136	56	268	212	50
28.	Pali	TW	8.1	2300	351.5	1472	70.9	42.5	270	67	206	42	232	379	10

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
29.	Sadpur	HP	7.5	1500	423.52	960	75.6	57.2	116	65	172	72	246.5	272	60
30.	Surajpur	HP	8.2	1400	438.08	896	82.9	56.3	369	46	362	18	204.2	286	8
31.	Ghori Bachera	HP	9.1	2500	452.62	1600	85.6	58.2	242	30	1000	56	266.1	498	10
32.	Brandi	HP	7.6	700	328.74	448	55.4	46.4	109	30	236	52	109	152	10
33.	Bahmanfur	HP	7.6	1000	297.05	640	52.4	40.5	156	55	252	70	152	156.2	10
34.	Tughalpur	HP	7.5	600	230.32	384	42.6	30.2	170	28	132	42	136	272.6	18
35.	Jhatta	HP	6.2	800	173.66	512	32.4	22.6	160	40	196	60	142	258.9	15
36.	Badoli	HP	6.7	700	257.84	448	33.6	42.4	96	52	238	116	158	312.6	30
37.	Yoqutur	HP	6.5	900	277.4	576	34.7	46.5	102	52	304	102	108	358	25
38.	Bhopani	TW	6.3	700	206.27	448	29.7	32.2	132	45	400	48	278	232	28
39.	Rajpur Kalan	TW	6.1	800	258.71	512	36.9	40.6	128	50	128	36	142	217	27
40.	Dhnkora	TW	6.7	600	240.74	384	32.5	38.9	108	12	502	58	124	152	35
41.	Dadha	TW	7.9	1300	293.66	832	47.6	42.6	134	10	132	64	82	256.2	32
42.	Sirsa	HP	7.9	1000	252.46	640	50.8	30.6	146	8	308	73	126	262	12
43.	Manhcha	HP	9.2	2300	391.74	1472	80.6	46.4	356	18	618	108	352	241	35
44.	Luksar	HP	7.5	500	301.24	320	56.7	38.9	166	46	178	58	128	152	12
45.	Chaharpur Khadar	HP	7.8	800	334.19	512	62.5	43.4	194	26	258	40	178	128	10

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
46.	Naya Gharbara	HP	7.5	1000	331.64	640	62.3	42.9	196	39	262	104	92	142	47
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
47.	Dadupur	TW	7.5	1300	387.41	832	68.7	52.6	204	15	156	60	118	175	50
48.	Grdhnur	HP	8.0	1800	373.87	1152	70.5	48.2	228	32	204	59	135	520	55
49.	Janalpur	HP	9.2	2800	448.57	1792	80.7	60.2	470	12	1106	96	350	777	58
50.	Blaspur	TW	8.5	1100	331.2	704	63.6	42	136	65	252	58	266	212	40
51.	Chiti	TW	8.1	1600	406.1	1024	70.6	56	426	43	342	56	352	272	54
52.	Astaula	HP	9.2	1900	417.45	1216	81.7	52	370	82	562	52	225	208	65
53.	Kanarsa	HP	8.2	1500	409.05	960	68.5	58	114	65	472	42	16	230	20
54.	Chuharpur Bangan	TW	8.3	1400	398.47	896	70.5	54.2	168	52	166	36	302	288	12
55.	Atta Gujran	HP	7.2	800	201.68	512	27.7	32.3	406	35	158	62	208	480	60
56.	Dankaur	HP	7.9	1500	239.01	960	40.5	33.6	265	12	246	240	156	291	8
57.	Wair	HP	8.5	2000	270.87	1280	45.7	38.2	505	20	262	22	164	156	55
58.	Sikandarabad	HP	9.2	2800	409.42	1792	71.6	56.2	242	55	342	70	204	152	72
59.	Rajpur Khurd	HP	9.6	2600	397.48	1664	72.4	52.8	114	36	792	142	272	570	75
60.	Kotderi	TW	9.2	2100	420.66	1344	65.6	62.6	301	20	826	138	142	300	25
	Average		**7.81**	**1330**	**319.37**	**858.4**	**56.83**	**43.24**	**235.91**	**38.0**	**297.61**	**68.26**	**211.18**	**277.62**	**29.66**

Appendix VII C. Range of concentration of various major and Trace elements in Shallow groundwater Samples and their comparison with W.H.O. (1993) and B.I.S. (1991) Drinking Water Standards.

	(BIS 1991)		W.H.O. (1993)		Conc. In the study area (mg/l)	
Constituents	Highest desirable level	Max. permissible level	Highest desirable level	Max. Permissible limits	2006	2007
pH	6.5-8.5	6.5-9.5	7-8.5	6.5-9.2	6.2-9.6	6.1-9.6
Total Hardness	300	600	100	500	221.14-498.78	173.66-466.97
TDS	500	2000		1000	96-1728	320-1792
Calcium	75	200	75	200	30.5-86.8	27.7-85.6
Magnesium	30	100		50	30.4-70.8	22.6-65.6
Sodium				200	114-556	96-532
Chloride	250	1000	200	600	98-412.6	16-392
Sulphate	200	400	200	400	26-786.3	112-777
Fluoride	0.6-1.2	1.5				
Nitrate	45	100	10	50	11-72	8-75
Copper	0.05	1.5	0.05	15	0.004-1.522	
Iron	0.3	1	0.1	1	0.003-1.731	
Lead	0.1			0.1	0.011-0.498	
Manganese	0.1	0.5	0.05	0.5	0.004-0.894	
Cadmium	0.01	0.01		0.01	0.002-3.509	
Nickel	0.1	0.3				
Cobalt						
Chromium	0.05	0.05		0.05	0.003-0.382	
Zinc	0.1	15	5	15	0.004-6.239	
Selenium	0.01	0.1				

Appendix VII D : concentration of major ions in groundwater samples in Pre-monsoon 2006. (epm)

S.No	Ca^{++}	Mg	Na	K	HCO_3	CO_3	Cl^-	SO_4^{--}	NO_3	Na%	SAR
1	2	3	4	5	6	7	8	9	10	11	12
1.	2.759	3.751	7.224	2.044	3.081	2.733	6.225	3.789	0.241	58.740	4.003
2.	2.370	3.496	20.296	1.817	5.113	3.766	5.305	3.876	0.403	79.033	11.850
3.	2.410	3.323	7.138	0.511	6.851	5.732	5.478	4.515	0.290	57.157	4.215
4.	2.280	4.754	9.202	0.454	2.769	3.799	6.236	3.951	0.354	57.852	4.906
5.	2.674	4.820	13.588	1.249	3.589	2.733	6.148	3.510	0.564	66.438	7.019
6.	3.273	3.981	7.052	1.476	2.556	1.733	10.133	6.508	0.241	54.035	3.702
7.	3.517	3.158	7.568	1.476	2.999	1.466	8.877	8.619	0.290	57.531	4.142
8.	2.135	2.599	20.554	2.215	3.212	1.866	7.611	3.934	0.419	82.784	13.358
9.	2.190	2.780	22.274	1.760	3.212	2.133	9.712	4.413	0.725	82.862	14.128
10.	1.911	2.632	23.908	1.817	6.047	3.066	7.579	12.741	0.435	84.989	15.862
11.	2.789	3.504	13.846	0.738	4.130	2.599	8.988	5.954	0.838	69.855	7.805
12	2.634	3.438	9.804	0.908	1.999	1.866	11.717	6.495	0.290	63.819	5.626
13.	2.440	2.763	9.288	1.817	4.507	3.166	8.988	2.664	0.258	68.092	5.757
14.	3.068	3.602	5.418	0.511	3.097	1.399	3.396	5.246	0.290	47.053	2.966
15.	3.183	3.635	17.802	0.397	6.556	0.933	5.168	5.413	0.419	72.742	9.640
16.	3.537	5.067	5.246	1.363	4.572	1.866	5.565	5.579	0.629	43.444	2.529
17.	2.784	3.142	4.988	1.476	3.048	2.033	6.605	5.454	0.677	52.171	2.897
18.	3.752	4.022	6.536	1.476	2.704	0.733	6.213	7.869	0.564	50.753	3.314
19.	3.937	5.692	11.696	0.454	7.785	3.066	4.589	7.411	0.741	55.787	5.330

1	2	3	4	5	6	7	8	9	10	11	12
20.	3.423	3.191	6.966	1.363	4.294	1.966	7.997	13.991	0.516	55.735	3.830
21.	2.175	2.928	7.224	1.476	4.687	2.099	8.307	7.994	0.564	63.029	4.522
22.	2.634	2.681	9.288	1.022	5.507	1.599	7.043	3.934	0.290	65.978	5.696
23.	3.478	3.142	17.888	0.454	2.819	2.133	7.440	3.456	0.258	73.479	9.831
24.	3.423	4.647	5.676	0.511	4.408	2.367	5.191	3.789	0.193	43.394	2.825
25.	3.632	5.231	6.192	0.738	2.999	1.966	8.008	3.997	0.612	43.877	2.941
26.	4.161	5.824	23.22	1.249	4.621	1.599	6.958	4.413	0.193	71.018	10.391
27.	3.522	5.067	9.976	1.874	2.360	2.066	8.145	5.121	0.951	57.974	4.813
28.	3.732	4.326	11.266	1.988	3.802	1.599	6.889	8.619	0.258	62.186	5.612
29.	3.932	5.478	6.106	2.044	3.048	2.799	7.349	6.495	1.048	46.413	2.814
30.	4.071	5.774	16.168	1.363	6.211	0.799	6.148	7.536	0.258	64.034	7.286
31.	4.331	5.470	10.836	0.908	19.864	2.099	7.986	11.971	0.193	54.509	4.894
32.	3.008	4.326	5.246	1.022	4.392	2.033	3.578	3.364	0.258	46.076	2.739
33.	2.804	3.964	7.998	1.760	4.458	2.533	4.998	3.795	0.177	59.043	4.347
34.	2.509	3.175	7.482	0.908	2.442	1.599	4.203	5.875	0.241	59.610	4.437
35.	1.926	2.500	6.966	1.306	3.589	2.166	5.026	6.029	0.354	65.140	4.682
36.	1.756	3.800	4.902	1.590	4.523	4.266	5.185	7.541	0.435	53.882	2.940
37.	1.706	4.022	5.074	1.476	5.179	3.866	3.592	8.046	0.435	53.345	2.997
38.	1.586	2.895	5.934	1.363	6.326	2.166	8.875	4.934	0.532	61.947	3.963
39.	1.931	3.800	6.106	1.647	2.278	1.633	4.799	0.541	0.564	57.496	3.606
40.	1.776	3.504	4.988	0.511	8.424	2.299	4.032	3.393	0.677	51.013	3.069
41.	2.305	4.178	6.106	0.454	2.425	2.599	2.783	5.446	0.693	50.292	3.391

1	2	3	4	5	6	7	8	9	10	11	12
42.	2.425	2.977	6.536	0.397	5.703	2.866	4.231	5.854	0.241	56.203	3.976
43.	3.937	5.174	16.254	0.738	11.079	4.066	10.865	4.801	0.516	65.095	7.615
44.	2.734	3.422	7.654	1.476	3.097	2.166	4.146	3.497	0.258	59.727	4.362
45.	3.008	3.997	9.288	0.965	4.556	1.533	5.452	2.852	0.274	59.405	4.962
46.	3.283	4.096	9.804	1.192	4.556	3.732	3.124	3.227	0.854	59.840	5.103
47.	3.522	4.845	9.976	0.340	2.982	2.233	4.032	3.914	0.919	55.214	4.877
48.	3.682	4.639	10.578	1.022	3.540	2.166	4.629	11.086	1.000	58.227	5.185
49.	4.131	5.634	20.554	0.397	18.422	3.532	10.740	16.370	1.048	68.205	9.301
50.	3.453	3.997	6.364	2.215	4.408	2.066	7.946	3.705	0.677	53.519	1.241
51.	3.662	5.050	17.845	1.363	6.031	2.266	10.269	6.412	0.774	68.793	0.478
52.	4.206	5.486	16.125	2.499	9.653	1.966	6.716	4.080	0.983	65.769	0.915
53.	3.532	5.248	5.504	1.817	7.785	1.633	4.901	4.705	0.405	45.468	1.050
54.	3.672	5.14125	7.654	1.363	2.819	1.399	8.883	6.495	0.290	50.570	0.692
55.	1.521	3.167	17.845	0.795	2.753	2.266	6.134	9.985	0.903	79.900	0.283
56.	2.514	3.504	11.696	0.426	4.687	8.532	4.884	6.495	0.258	66.820	0.184
57.	2.574	4.672	22.188	0.511	4.736	0.933	5.055	3.726	1.000	75.799	0.162
58.	3.817	5.667	11.868	1.363	6.015	2.299	6.020	3.518	1.112	58.245	0.570
59.	3.902	5.149	5.504	1.306	14.357	5.199	8.224	12.204	1.161	42.935	0.757
60.	3.483	5.149	14.104	0.738	14.734	5.399	4.771	6.6249	0.451	63.226	0.287

Appendix VII E : concentration of major ions in groundwater samples in Post-monsoon 2007. (epm)

S.No	Ca^{++}	Mg	Na	K	HCO_3	CO_3	Cl^-	SO_4^{--}	NO_3	Na%	SAR
1	2	3	4	5	6	7	8	9	10	11	12
1.	2.504	3.479	6.536	1.662	2.540	2.599	6.248	4.122	0.193	57.803	3.778
2.	2.210	3.183	19.479	1.406	4.785	3.466	5.396	4.164	0.290	79.474	11.861
3.	2.115	2.681	6.665	0.306	6.490	5.066	5.793	4.684	0.258	59.237	4.303
4.	1.921	3.496	8.901	0.306	2.507	3.466	6.304	3.705	0.403	62.959	5.408
5.	2.180	4.705	12.642	0.894	3.278	2.866	5.793	3.123	0.483	66.283	6.813
6.	2.864	3.479	6.536	1.125	2.229	1.866	10.224	6.662	0.209	54.702	3.669
7.	3.333	2.500	7.095	1.227	2.507	1.666	8.576	8.910	0.322	58.788	4.154
8.	1.911	2.755	20.425	1.841	2.687	1.866	7.156	3.456	0.467	82.672	13.370
9.	1.971	2.105	20.726	1.431	2.573	1.866	9.031	3.997	0.774	84.459	14.516
10.	1.676	2.262	22.876	1.662	5.228	2.533	6.702	12.242	0.403	86.168	16.300
11.	2.619	2.607	12.986	0.562	4.031	2.399	8.576	5.663	0.806	72.159	8.032
12	2.280	2.739	9.288	0.639	1.835	1.733	11.132	5.787	0.258	66.416	5.862
13.	2.125	2.410	8.6	0.971	4.195	3.066	8.633	2.331	0.193	67.847	5.710
14.	2.779	3.718	5.59	0.383	2.884	1.499	3.271	5.413	0.354	47.899	3.101
15.	3.008	3.298	18.576	0.306	4.621	0.833	5.026	5.517	0.403	74.960	10.460
16.	3.183	4.022	4.472	1.073	4.359	1.599	5.168	5.579	0.483	43.490	2.355
17.	2.405	2.920	4.644	1.176	2.917	1.866	5.793	5.871	0.725	52.219	2.845
18.	3.423	3.825	6.106	1.227	2.606	0.599	5.964	8.452	0.516	50.291	3.207
19.	3.517	5.396	11.008	0.306	7.686	2.733	4.26	7.745	0.661	55.933	5.214
20.	3.173	3.298	6.536	1.073	4.031	1.866	7.531	13.533	0.435	54.03	3.633
21.	2.285	2.541	6.708	1.406	4.146	2.166	7.895	7.328	0.548	62.699	4.317
22.	2.674	2.196	8.772	0.767	4.949	1.399	6.674	3.372	0.225	66.19	5.620
23.	3.517	2.533	18.705	0.357	2.507	1.933	6.39	3.539	0.161	75.904	10.753
24.	3.313	4.055	4.644	0.511	4.425	2.166	4.998	3.851	0.241	41.163	2.419
25.	3.502	4.557	5.676	0.715	2.753	1.733	7.895	4.330	0.483	44.228	2.827
26.	4.271	5.075	22.016	1.278	4.753	1.399	6.702	4.164	0.129	71.364	10.184
27.	3.368	4.351	8.6	1.483	2.229	1.866	7.611	4.413	0.806	56.637	4.377
28.	3.537	3.496	11.61	1.713	3.376	1.399	6.588	7.890	0.161	65.447	6.190
29.	3.772	4.705	4.988	1.662	2.819	2.399	7.000	5.663	0.967	43.959	2.422
30.	4.136	4.631	15.867	1.176	5.933	0.599	5.799	5.954	0.129	66.030	7.578
31.	4.271	4.787	10.406	0.767	16.39	1.866	7.557	10.368	0.161	55.224	4.889

1	2	3	4	5	6	7	8	9	10	11	12
32.	2.764	3.816	4.687	0.767	3.868	1.733	3.095	3.164	0.161	45.317	2.583
33.	2.614	3.331	6.708	1.406	4.130	2.333	4.316	3.252	0.161	57.709	3.890
34.	2.125	2.484	7.31	0.715	2.163	1.399	3.862	5.675	0.290	63.516	4.814
35.	1.616	1.859	6.88	1.022	3.212	1.999	4.032	5.390	0.241	69.452	5.218
36.	1.676	3.487	4.128	1.329	3.900	3.866	4.487	6.508	0.483	51.380	2.568
37.	1.731	3.825	4.386	1.329	4.982	3.399	3.067	7.453	0.403	50.705	2.631
38.	1.482	2.648	5.676	1.150	6.556	1.599	7.895	4.830	0.451	62.301	3.949
39.	1.841	3.339	5.504	1.278	2.097	1.199	4.032	4.517	0.435	56.692	3.419
40.	1.621	3.199	4.644	0.306	8.227	1.933	3.521	3.164	0.564	50.660	2.990
41.	2.375	3.504	5.762	0.255	2.163	2.133	2.328	5.3340	0.516	50.580	3.360
42.	2.534	2.517	6.278	0.204	5.048	2.433	3.578	5.454	0.193	56.200	3.950
43.	4.021	3.816	15.308	0.460	10.129	3.599	9.996	5.017	0.564	66.794	7.732
44.	2.829	3.199	7.138	1.176	2.917	1.933	3.635	3.164	0.193	57.965	4.111
45.	3.118	3.570	8.342	0.664	4.228	1.333	5.055	2.664	0.161	57.384	4.561
46.	3.108	3.528	8.428	0.997	4.294	3.466	2.612	2.956	0.758	58.676	4.626
47.	3.428	4.326	8.772	0.383	2.556	1.999	3.351	3.643	0.806	54.141	4.454
48.	3.517	3.964	9.804	0.818	3.343	1.966	3.834	10.826	0.887	58.669	5.068
49.	4.026	4.952	20.21	0.306	18.127	3.199	9.94	16.177	0.935	69.558	9.538
50.	3.173	3.455	5.848	1.662	4.130	1.933	7.554	4.413	0.645	53.117	3.212
51.	3.522	4.606	18.318	1.099	5.605	1.866	9.996	5.663	0.871	70.488	9.085
52.	4.076	4.277	15.91	2.096	9.211	1.733	6.39	4.330	1.048	68.308	7.784
53.	3.418	4.771	4.902	1.662	7.736	1.399	0.454	4.788	0.322	44.492	2.422
54.	3.517	4.458	7.224	1.329	2.720	1.199	8.576	5.996	0.193	51.745	3.617
55.	1.382	2.656	17.458	0.894	2.589	2.066	5.907	9.993	0.967	81.961	12.284
56.	2.020	2.763	11.395	0.306	4.031	7.999	4.430	6.058	0.129	70.977	7.367
57.	2.280	3.142	21.715	0.5114	4.294	0.733	4.657	3.247	0.887	80.387	13.187
58.	3.572	4.623	10.406	1.406	5.605	2.333	5.793	3.164	1.161	59.037	5.140
59.	3.612	4.343	4.902	0.920	12.980	4.732	7.724	11.867	1.209	42.257	2.457
60.	3.273	5.149	12.943	0.511	13.538	4.599	4.032	6.246	0.403	61.499	6.306

Appendix VII F. Concentration of trace elements in groundwater samples (mg/l).

Sample No.	Cu	Pb	Zn	Fe	Mn	Cd	Cr
1	2	3	4	5	6	7	8
1.	0.16	0.321	2.530	0.921	0.010	0.016	0.080
2.	0.16	0.366	4.530	1.420	0.623	0.166	0.120
3.	0.14	0.011	2.640	0.862	0.063	0.166	0.140
4.	0.22	0.378	4.540	1.526	0.722	0.170	0.090
5.	0.18	0.498	4.530	1.646	0.734	0.005	0.150
6.	0.042	0.417	2.820	0.940	0.294	0.012	0.110
7.	0.38	0.116	1.550	0.808	0.410	0.022	0.070
8.	0.18	0.012	0.386	0.504	0.035	0.020	0.180
9.	0.02	0.044	0.339	0.003	0.062	0.008	0.010
10.	0.02	0.160	0.345	0.031	0.323	0.022	0.080
11.	0.04	0.250	2.108	1.321	0.132	0.002	0.051
12	0.018	0.312	4.001	1.731	0.198	Nd	Nd
13.	0.036	0.150	0.156	1.330	0.036	Nd	Nd
14.	0.026	0.098	0.446	0.008	0.049	Nd	Nd
15.	0.44	0.116	1.033	0.460	0.065	0.004	Nd
16.	0.022	0.232	1.120	0.340	0.125	0.002	0.005
17.	0.014	0.230	2.340	1.650	0.636	0.010	0.062
18.	0.012	0.321	2.241	1.701	0.611	0.004	0.052
19.	0.014	0.290	1.987	1.330	0.591	Nd	0.124
20.	0.46	0.233	1.456	1.340	0.512	0.006	0.058
21.	0.076	0.022	0.212	0.122	0.040	0.004	0.003
22.	0.004	0.026	0.038	0.005	0.032	0.002	0.006
23.	0.062	0.034	0.278	0.008	0.512	0.020	0.015
24.	0.162	0.016	0.154	0.275	0.070	0.044	0.075
25.	0.008	0.024	0.028	0.282	0.210	0.040	0.005
26.	0.098	0.062	0.062	0.420	0.004	0.002	0.012
27.	0.112	0.038	0.004	0.026	0.005	Nd	0.003
28.	0.082	0.018	0.064	0.034	0.312	0.004	0.04

1	2	3	4	5	6	7	8
29.	0.020	0.221	0.184	0.012	0.305	0.008	0.008
30.	0.046	0.266	2.024	0.525	0.012	Nd	0.006
31.	0.022	0.012	2.848	0.064	0.053	Nd	Nd
32.	0.210	0.318	1.060	0.012	0.081	Nd	Nd
33.	0.080	0.412	1.528	0.169	0.265	0.012	Nd
34.	0.080	0.111	0.144	0.335	0.075	0.008	0.014
35.	0.100	0.012	0.782	0.224	0.126	Nd	0.02
36.	1.240	0.044	1.060	0.134	Nd	Nd	0.003
37.	0.016	0.322	0.178	0.291	0.480	0.006	0.018
38.	0.018	0.055	0.056	0.420	0.047	0.020	0.382
39.	0.066	0.014	0.498	0.204	0.060	0.021	0.262
40.	0.008	0.016	0.498	0.116	0.612	Nd	0.042
41.	0.136	0.020	0.208	0.249	0.403	0.006	0.005
42.	0.358	0.014	1.505	0.302	0.072	0.014	0.005
43.	0.140	0.032	0.284	0.146	0.114	0.004	Nd
44.	0.621	0.014	0.044	0.216	0.150	0.006	Nd
45.	0.304	0.018	0.240	0.035	0.045	0.016	Nd
46.	0.230	0.028	0.054	0.021	0.062	Nd	Nd
47.	0.320	0.024	2.424	0.092	0.319	Nd	Nd
48.	0.320	0.208	0.350	0.180	0.075	0.008	0.003
49.	0.560	0.016	1.944	0.621	0.642	0.018	0.078
50.	0.320	0.012	2.072	0.020	0.804	Nd	Nd
51.	0.563	0.032	6.128	0.235	0.425	Nd	0.054
52.	0.438	0.35	6.239	0.989	0.514	3.072	0.216
53.	0.531	0.369	5.820	0.856	0.103	0.004	0.023
54.	0.156	0.021	1.995	1.234	0.125	0.014	0.043
55.	0.238	0.497	0.259	1.295	0.395	0.008	0.018
56.	1.522	0.048	4.530	0.987	0.484	3.504	0.078
57.	1.300	0.167	2.640	0.854	0.598	0.008	0.010
58.	0.936	0.326	4.540	0.549	0.521	0.002	0.012
59.	0.948	0.290	4.530	0.987	0.478	0.060	0.243
60.	0.538	0.233	2.820	0.824	0.894	0.020	0.124
Average	**0.25955**	**0.155283**	**1.6904**	**0.5707**	**8.377576**	**0.168667**	**0.068255**

Appendix VII G : Concentration of major ions in soil samples (mg/l).

S.No.	Location	pH	EC	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4
1.	Surya Nagar	7.8	900	40.6	35.8	104	18	102	115	102	320
2.	Sahibabad Industrial Area	8.1	1100	110.6	68.8	178	65	135	330	152	325
3.	Makhanpur	7.7	1300	82.4	62.2	168	30	160	310	156	378
4.	Meerut Road Industrial Area	7.5	800	64.1	50.2	158	25	102	230	98	310
5.	Behrampur	7.8	600	114	60.8	98	58	131	198	79	210
6.	Lal Kuan Industrial Area	8.3	950	78	62.4	248	50	142	268	108	201
7.	Mandoli	8.1	1450	85	50.4	104	35	145	435	180	451
8.	Chipyana Buzurg	7.6	1350	92	55.8	78.6	30	128	422	178	438
9.	Chora Sadatpur	7.2	1500	50	78.4	82.4	38	165	478	201	415
10.	Naya Bans	8.3	1600	55.4	66.4	78.4	42	169	575	235	485
11.	Gejah	7.3	1100	19.2	63.2	189.2	62	50.2	48.6	59.3	32.3
12.	Bisrakh	7.6	1300	85.9	68.7	93.6	49	49.2	58.2	65.1	75.6
13.	Tusiana	7.8	900	78.24	71.2	201.3	61	58.3	35.4	74.2	72.17
14.	Tilaput	8.1	1700	91.39	75.2	193.39	72	60.2	28.3	90.2	78.3
15.	Pali	7.5	2000	106.2	81.2	210.4	76	61.2	61.1	78.2	68.5
16.	Sadatpur	7.9	1500	143.3	93.43	213.4	59	33.3	18.6	85.3	58.7
17.	Tughalpur	8.2	1400	96.32	59.6	262.1	44	28.6	15.2	81.6	60
18.	Bhopani	8.3	1600	89.23	62.34	279.1	75	35.5	25.2	48.6	65
19.	Dadha	7.3	900	151.2	93.29	292	82	62.6	23.6	55.2	165.2
20.	Luksar	7.9	800	29.23	52.1	301.02	63	69.5	22.2	73.2	178.3
21.	Chiti	8.2	800	92.32	61.2	353.2	80	59.2	17.5	111.6	212.3
22.	Kanarsa	7.6	1200	78.62	59.39	391.6	90.39	49.1	15.3	12.2	79.9
23.	Atta Gujran	7.8	900	81.2	695.2	301.4	86.2	45.3	11.1	78.1	85.8
24.	Wair	8.1	1700	96.3	63.2	279.32	78.3	42.2	16.2	72.3	95.5
25.	Sikandrabad	8.3	1500	86.16	61.13	281.4	81.2	39.3	5.6	68.2	96.3
	Average	7.852	1234	83.876	90.063	205.593	58.003	84.908	150.524	101.692	198.274

Appendix VII H : Concentration of trace elements in soil samples (mg/l).

Sample No.	Cu	Zn	Fe	Mn
1.	10.4	1.39	8.66	16.26
2.	8.6	1.13	6.89	4.93
3.	4.8	0.26	1.33	11.96
4.	4.2	3.39	4.64	8.96
5.	2.04	9.10	3.55	7.72
6.	1.62	8.62	2.45	7.11
7.	1.49	5.66	2.23	4.11
8.	1.23	4.71	3.11	3.33
9.	3.33	6.80	17.23	12.00
10.	2.21	1.26	8.61	6.92
11.	1.39	8.20	Nd	Nd
12.	0.99	8.00	Nd	Nd
13.	0.10	10.20	8.23	10.42
14.	1.49	2.30	8.63	24.14
15.	2.05	2.10	9.83	2.05
16.	2.83	3.30	3.55	Nd
17.	2.01	3.60	11.23	23.2
18.	2.22	1.20	8.60	20.2
19.	3.34	1.33	4.50	Nd
20.	3.00	3.30	4.90	Nd
21.	1.25	1.23	3.80	12.4
22.	1.39	1.92	3.80	10.22
23.	1.20	1.13	3.71	11.96
24.	4.80	2.34	2.29	8.96
25.	4.25	3.20	2.31	8.71
Average	**2.8892**	**3.8268**	**5.829565**	**10.778**